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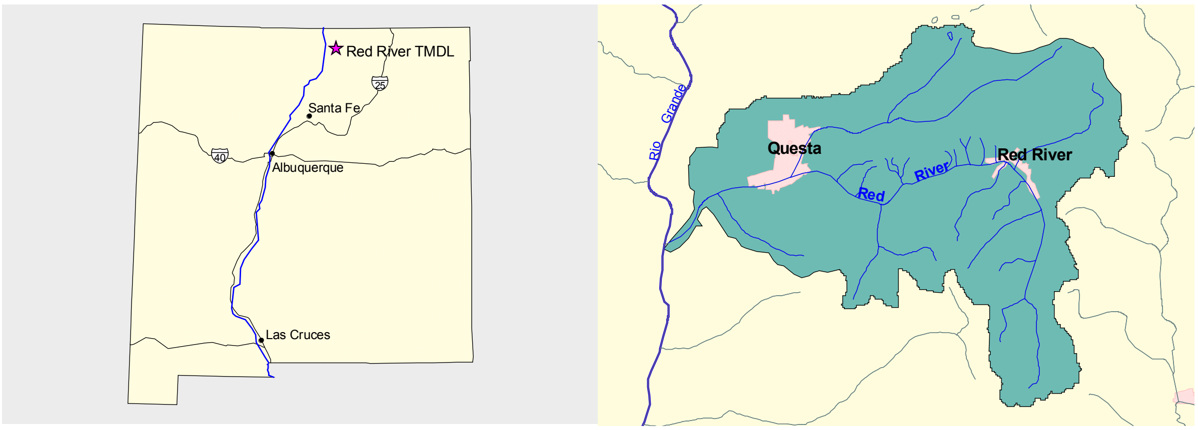
TOTAL MAXIMUM DAILY LOAD FOR METALS (CHRONIC AND ACUTE ALUMINUM), STREAM BOTTOM DEPOSITS, AND TURBIDITY FOR LISTED REACHES IN THE RED RIVER WATERSHED



Summary Table

New Mexico Standards Segment	Rio Grande Basin – Red River Watershed, 20.6.4.122 and 20.6.4.123 NMAC (formerly 2119 and 2120)
Waterbody Identifier	• Red River from Placer Creek to the headwaters (Upper Red River), 8.0 mi. • Red River from mouth on Rio Grande to Placer Creek (Middle and Lower Red River), 20.2 mi. • Bitter Creek from mouth on Red River to headwaters, 7.1 mi. • Pioneer Creek from mouth on Red River to headwaters, 4.3 mi. • Placer Creek from mouth on Red River to headwaters, 1.3 mi. • Cabresto creek from mouth on Red River to headwaters, 14.6 mi.
Parameter of Concern	Metals (chronic aluminum) - Upper Red River, Middle and Lower Red River, Cabresto Creek Metals (acute aluminum) - Bitter Creek, Placer Creek Stream bottom deposits - Bitter Creek Turbidity - Pioneer Creek
Uses Affected	• Upper Red River, Bitter Creek, Pioneer Creek, Placer Creek, Cabresto Creek – high quality coldwater fishery. • Middle and Lower Red River – coldwater fishery, livestock watering, irrigation.
Geographic Location	Rio Grande Basin – Red River Watershed Bitter Creek (URG1-20450) Pioneer Creek (URG1-20430) Placer Creek (URG1-20510) Cabresto Creek (URGI-20410)
Scope/size of Watershed	• 41 mi^2 (Upper Red River) • 147 mi^2 (Middle and Lower Red River) • 10 mi^2 (Bitter Creek) • 5.3 mi^2 (Pioneer Creek) • 2.4 mi^2 (Placer Creek) • 40.4 mi^2 (Cabresto Creek)

Land Type	Ecoregion: Sangre de Cristo Mountains
Land Use/Cover	• Upper Red River: Forest (90%), Rangeland (4%), Barren (4%), Built-up (2%) • Middle and Lower Red River: Forest (86%), Agriculture (4%), Mining (3%), Rangeland (3%), Barren (2%), Built-up (2%) • Bitter Creek: Forest (99%), Built-up (1%) • Pioneer Creek: Forest (94%), Built-up (6%) • Placer Creek: Forest (95%), Built-up (5%) • Cabresto Creek: Forest (91%), Barren (5%), Agriculture (2%), Rangeland (2%)
Identified Sources	• Upper Red River: Natural, Resource extraction, Road maintenance/runoff • Middle and Lower Red River: Rangeland, Resource extraction, Road maintenance/runoff • Bitter Creek (acute aluminum): Resource extraction, Road maintenance/runoff, Recreation, Natural • Bitter Creek (stream bottom deposits): Rangeland, Resource extraction, Road maintenance/runoff, Recreation, Removal of Riparian Vegetation, Streambank Modification/Destabilization • Pioneer Creek: Resource extraction, Recreation, Removal of Riparian Vegetation, Streambank Modification/Destabilization • Placer Creek: Natural, Resource extraction • Cabresto Creek: Natural, Road maintenance/runoff
Watershed Ownership	• Upper Red River: Forest Service (93%), Private (7%) • Middle and Lower Red River: Forest Service (84%), Private (10%), BLM (6%) • Bitter Creek: Forest Service (100%) • Pioneer Creek: Forest Service (100%) • Placer Creek: Forest Service (100%) • Cabresto Creek: Forest Service (94%), Private (6%)
Priority Ranking	1 - Middle and Lower Red River 3 - Upper Red River, Bitter Creek, Placer Creek, Cabresto Creek 4 - Pioneer Creek
Threatened and Endangered Species	No
TMDL for:	
Metals (chronic aluminum)	
Upper Red River	WLA(0) + LA(18.6) + MOS(4.6)= **23.2 lbs/day**
Middle Red River [+]	WLA(2.63) + LA(468.33) + MOS(117.74)= **588.7 lbs/day (based on bioassessment data)**
Lower Red River	WLA(0.34) + LA(65.1) + MOS(16.36)= **81.8 lbs/day**
Cabresto Creek	WLA (0) + LA (12.6) + MOS (3.2) = **15.8 lbs/day**
Metals (acute aluminum)	
Bitter Creek	WLA(0) + LA(40.0) + MOS(10.0)= **50.0 lbs/day (based on bioassessment data)**
Placer Creek	WLA(0) + LA(8.0) + MOS(2.0)= **10.0 lbs/day**
Stream bottom deposits	
Bitter Creek	WLA(0) + LA(22.5) + MOS(7.5)=**30 % fines (72% reduction)**
Turbidity (as TSS)	
Pioneer Creek	WLA(0) + LA(561.4) + MOS(99.1)= **660.5 lbs/day**

[+] The Middle Red River includes the Red River from the confluence of Placer Creek to the confluence of Columbine Creek.

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List of Abbreviations

Al	Aluminum
ARD	Acid rock drainage
BLM	Bureau of Land Management
BMP	Best management practice
CWA	Clean Water Act
CWAP	Clean Water Action Plan
CWF	Coldwater fishery
DBS&A	Daniel B. Stephens & Associates, Inc.
EPA	United States Environmental Protection Agency
GIS	Geographic Information System
GWQB	Ground Water Quality Bureau
HQCWF	High quality coldwater fishery
IRR	Irrigation
LA	Load allocation
lb/day	Pounds per day
LW	Livestock watering
mgd	Million gallons per day
mg/L	Milligrams per liter
MOS	Margin of safety
MOU	Memorandum of understanding
µg/L	Micrograms per liter
NEPA	National Environmental Policy Act
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMSHTD	New Mexico State Highway and Transportation Department
NMWQCC	New Mexico Water Quality Control Commission
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint source
NTU	Nephelometric turbidity units
RFP	Request for Proposals
SBD	Stream bottom deposits
SWCA	SWCA Inc.
SWQB	Surface Water Quality Bureau
TMDL	Total maximum daily load
TSS	Total suspended solids
USFS	United States Forest Service
USGS	United States Geological Survey
UWA	Unified Water Assessment
WLA	Waste load allocation
WRAS	Watershed restoration action strategy
WWTP	Wastewater treatment plant

EXECUTIVE SUMMARY

Red River near former Zwergle gage station

This report addresses Section 303(d) of the Federal Clean Water Act, which requires states to develop Total Maximum Daily Load (TMDL) management plans for surface water bodies that are determined to be impaired with respect to their designated uses. TMDLs are defined in 40 CFR Part 130 as the sum of the individual Waste Load Allocations (WLA) for point sources and Load Allocations (LA) for nonpoint sources (NPS), including a margin of safety (MOS), and natural background conditions. A TMDL documents the amount of a pollutant a water body can assimilate without violating the water quality standards set by the state. It also allocates that load capacity to known point sources and nonpoint sources at a given flow.

The Red River (from its confluence with the Rio Grande), together with its tributaries and headwaters (upstream from the confluence of the main and west forks of the Red River), define the greater Red River Watershed of northern New Mexico. Sampling stations were established along the course of the river to evaluate the impact of tributary streams and to establish background conditions. As a result of this monitoring effort, multiple exceedances of New Mexico water quality standards for metals (chronic aluminum) were documented on the main stem of the Red River from its confluence with the Rio Grande to its headwaters, and on the Cabresto Creek tributary. In addition, waters in the Bitter Creek and Placer Creek tributaries were found to exceed the acute aluminum standard. The Pioneer Creek tributary is impaired with respect to turbidity, while Bitter Creek is impaired with respect to stream bottom deposits.

The TMDLs for the impaired water bodies of the Red River Watershed and a general implementation plan for activities to be established in the watershed are included in this document. The plan discusses the use of biological data to assess the attainment of aquatic life uses in the Red River. TMDL goals for Bitter Creek and the middle reach of the Red River were based on a biological assessment. The Watershed Protection Section of New Mexico's Surface Water Quality Bureau (SWQB) will implement this plan with regard to nonpoint sources, while the United States Environmental Protection Agency (EPA) will implement the portions of the plan related to point sources.

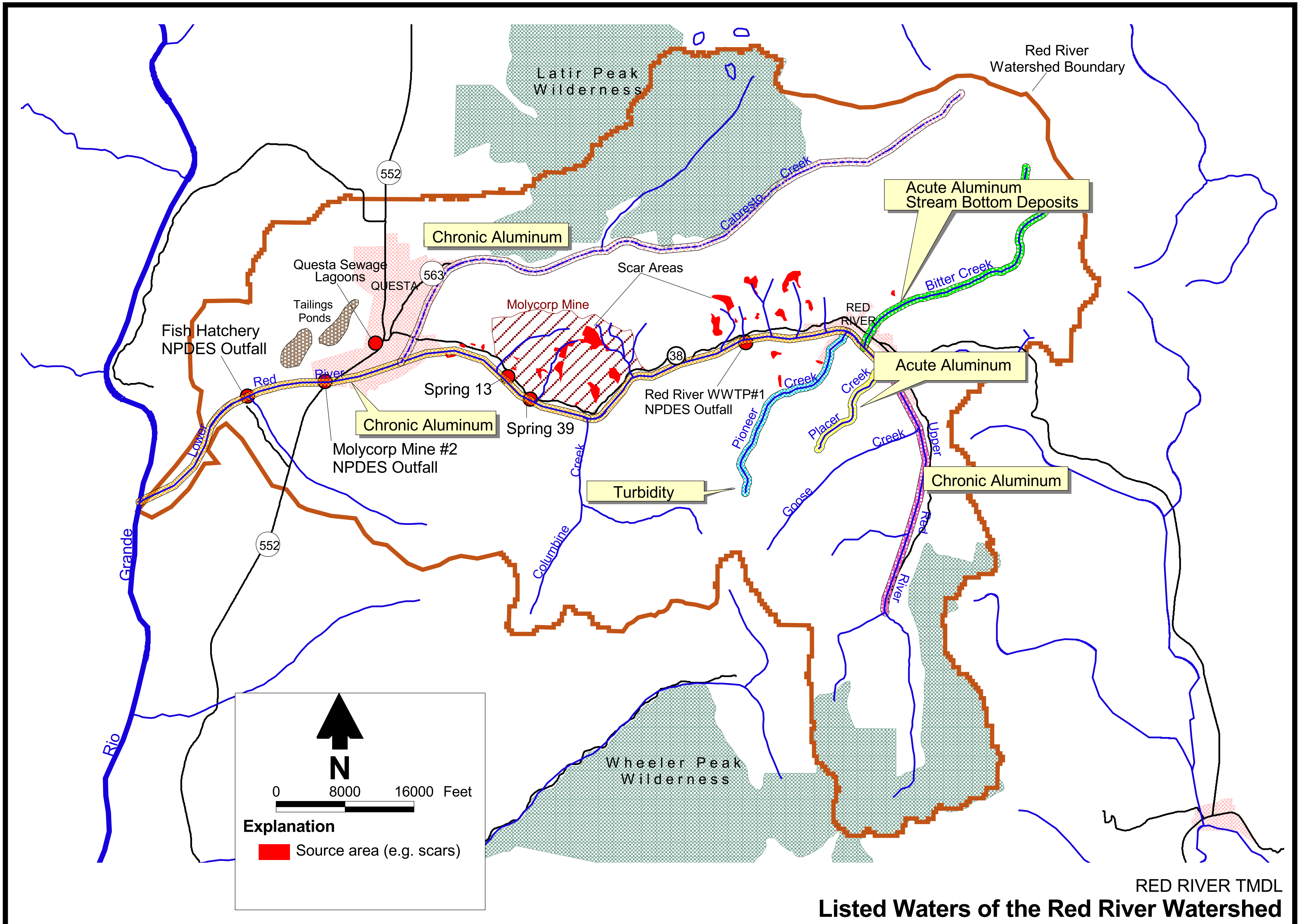
Implementation of watershed improvement activities recommended in this document will involve participation of all interested and affected parties and will require the collection of additional water quality data. Consequently, this document is considered to be an evolving management plan, and load targets will be reexamined and potentially revised according to periodic analysis of new data. If new data indicate that the targets used in this analysis are not appropriate, or if new standards are adopted, the load capacity will be adjusted accordingly. When water quality standards have been achieved, the water body will be removed from the list of priority TMDLs maintained by the SWQB.

INTRODUCTION

The consulting team of Daniel B. Stephens & Associates, Inc. (DBS&A), SWCA Inc., (SWCA), and Dr. Tim Ward was contracted by the Surface Water Quality Bureau (SWQB) of the New Mexico Environment Department (NMED) to develop the Red River Watershed Total Maximum Daily Loads (TMDLs) and issue a final report. A TMDL establishes the load(s) or amount of pollutant(s) that can be introduced into a watercourse or stream reach from its contributing watershed on a daily basis, without resulting in a violation of applicable state water quality standards. A TMDL also estimates and allocates loads among all of the pollutant sources throughout the impaired watershed or watercourse segment. The allocations are used to assess the most appropriate pollution control measures and best management practices (BMPs) that can be implemented to achieve compliance with water quality standards. Exceedances of water quality standards suggest that the receiving water body is impaired with respect to its designated use(s).

As part of an effort to maintain and improve the quality of New Mexico's surface waters, the SWQB has developed a schedule and timeline for completing priority TMDLs for resources that are impaired or otherwise do not support their designated use. Designated waters within the Red River Watershed are included on the SWQB 303(d) List of Assessed Stream and River Reaches for TMDL assessment (NMED, 2001a). Impairments implied by earlier studies in the area (e.g., Allen et al., 1999) were delineated on the basis of seasonal water quality sampling and analyses conducted by the SWQB at stations located along the course of the Red River and its tributary streams and seeps. As a result of this monitoring effort, exceedances of the New Mexico water quality standard for aluminum were detected in the Red River and some of its tributaries. Exceedances for stream bottom deposits and turbidity were also confirmed for some of its tributaries.

This report presents TMDLs for those waters of the Red River that are listed as impaired on the 303(d) list (Figure 1). This includes the main stem of the Red River from its mouth on the Rio Grande to the confluence of Placer Creek (Middle and Lower Red River), the main stem of the Red River from the confluence of Placer Creek to its headwaters (Upper Red River), and the Cabresto Creek tributary. These segments are listed as impaired due to multiple exceedances of New Mexico water quality standards for chronic aluminum. In addition, waters in the Bitter Creek and Placer Creek tributaries exceed the acute aluminum standard, Pioneer Creek is impaired with respect to turbidity, and Bitter Creek is impaired with respect to stream bottom deposits (NMED, 2001a). Designated uses of the Middle and Lower Red River segment include coldwater fishery (CWF), livestock watering (LW), and irrigation (IRR). The Upper Red River and other listed tributaries are designated for use as a high quality coldwater fishery (HQCWF). Both CWF and HQCWF uses require consistently high water quality.



RED RIVER TMDL

Listed Waters of the Red River Watershed

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Figure 1

The TMDLs for the Red River Watershed are based on an analysis of physical and chemical data for the system and on the results of mathematical modeling. A TMDL includes contaminant loads from point sources and nonpoint sources. Point sources are allocated in the Waste Load Allocations (WLAs), while nonpoint sources (NPSs), which include natural background pollutants, are included in the load allocations (LAs). These allocations include allowances for future growth and development in the area. The TMDLs also provide a margin of safety (MOS) based on the uncertainty or variability in the data, the point and NPS load estimates, and the modeling analysis.

Analysis of the water quality database and modeling were used to determine the WLAs, LAs, and MOSs for the critical pollutants. Critical pollutants that may be impairing the designated uses of the Red River Watershed include aluminum, sediments, and turbidity. The watershed receives waters that drain both mineralized (sulfide-bearing minerals) and unmineralized areas. Mineralized areas (which include undisturbed areas as well as areas developed and disturbed by mining and other activities) may be potential sources of aluminum and other pollutants due to the formation of acid rock drainage (ARD) that enters the river. The relatively pristine waters from the unmineralized areas also flow into the Red River, diluting concentrations of aluminum and raising pH values of waters derived from the mineralized areas. Neutralization of acidic water depresses aluminum solubility and results in precipitation of aluminum solids onto the steam bed (Theobold et al., 1963). In addition, sediments derived from erosion of soils and construction materials are entering and affecting the watershed.

BACKGROUND INFORMATION

The Red River, which originates in the Sangre de Cristo Range among New Mexico's highest peaks, including the 13,161-foot Wheeler Peak, is an important tributary to the Rio Grande. The river's sources are fed by relatively consistent patterns of orographic precipitation, including snowmelt and summer season convective storms. Figure 2 illustrates some of the major physiographic features along the Red River.

Red River near Questa gage station

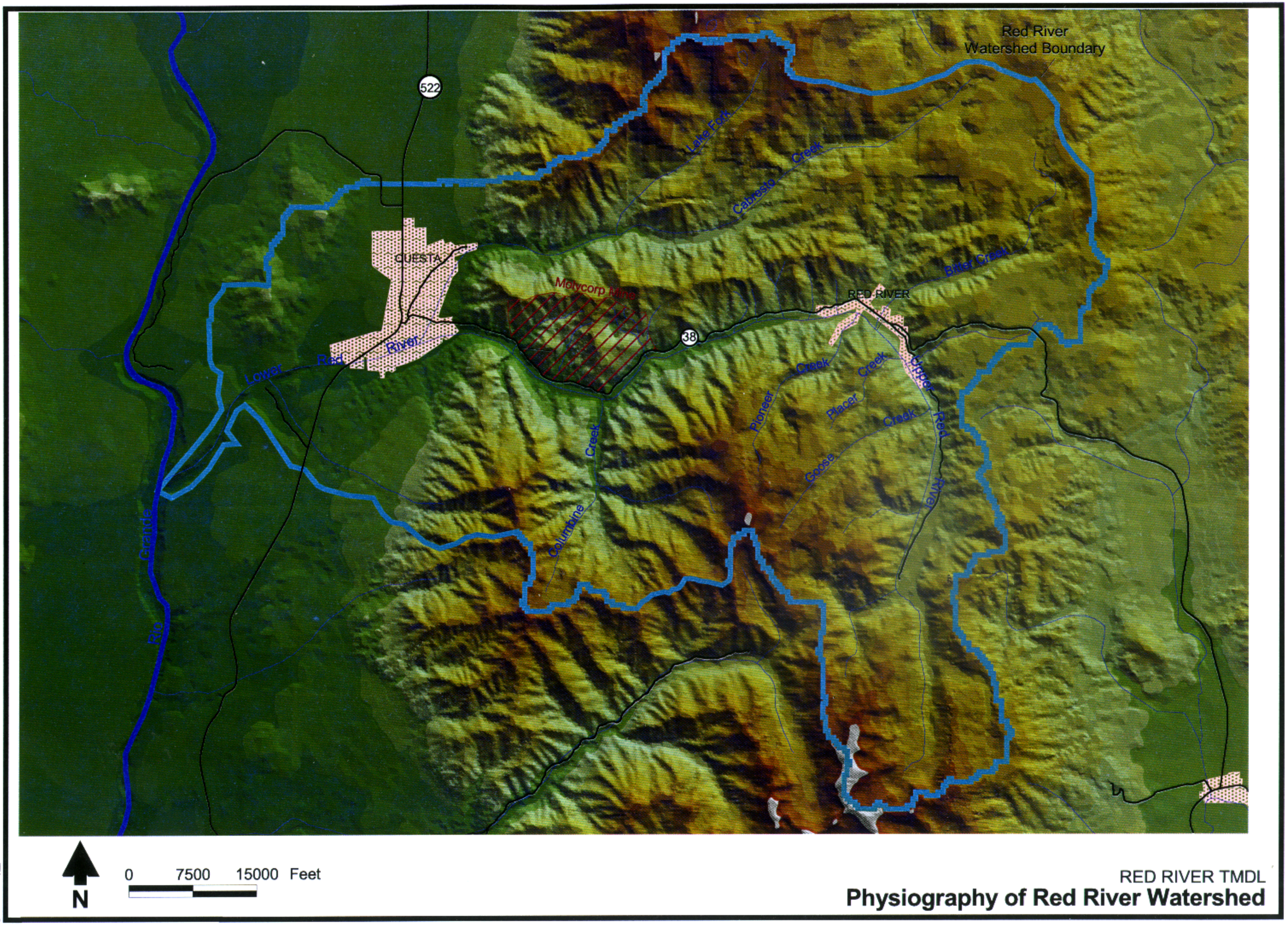
Watershed Characteristics

The Red River Watershed covers approximately 188 square miles in northern New Mexico. It is dominated by evergreen forest, but includes rangeland, agricultural and mining areas, barren lands, and built-up areas (Figure 3). Most of the land is managed by the United States Forest Service (USFS). A much smaller area (5%) is under the purview of the Bureau of Land Management (BLM) (Figure 4). The watershed consists almost entirely of Federal lands, with approximately 9% privately held land.

Geomorphology

The watershed has two distinct characters, owing to an abrupt change in geology along its course. Along its upper and middle reaches, in the high mountains of the Carson National Forest, the Red River is a freestone stream flowing across wide meadows and through narrow canyons. The gradient along this reach ranges from approximately 70 to 130 feet per mile, decreasing downstream. The terrain is derived from erosion and the river's downcutting into Precambrian igneous and metamorphic basement rocks and Tertiary volcanic intrusives (altered and unaltered). Cabresto Creek joins the Red River in the lower part of this section and is its largest tributary. During the irrigation season, which usually lasts from May through September, essentially the entire flow of this creek is diverted, disconnecting it from the Red River. A significant portion of the Cabresto Creek watershed is encompassed by the Latir Peak Wilderness area, which includes the northernmost reaches of the Red River Basin (Figure 1).

As it nears the Rio Grande Gorge, the Lower Red River has carved a deep canyon through the Quaternary alluvial deposits and Tertiary conglomerates and volcanic flows of the Rio Grande rift system. The average gradient along this reach is approximately 150 feet per mile. In this section, the river flows through boulder-choked pockets of water and is similar in character to the Rio Grande itself. The lowermost section of the river is included in the Rio Grande Wild and Scenic River area.



RED RIVER TMDL

Physiography of Red River Watershed

Figure 2

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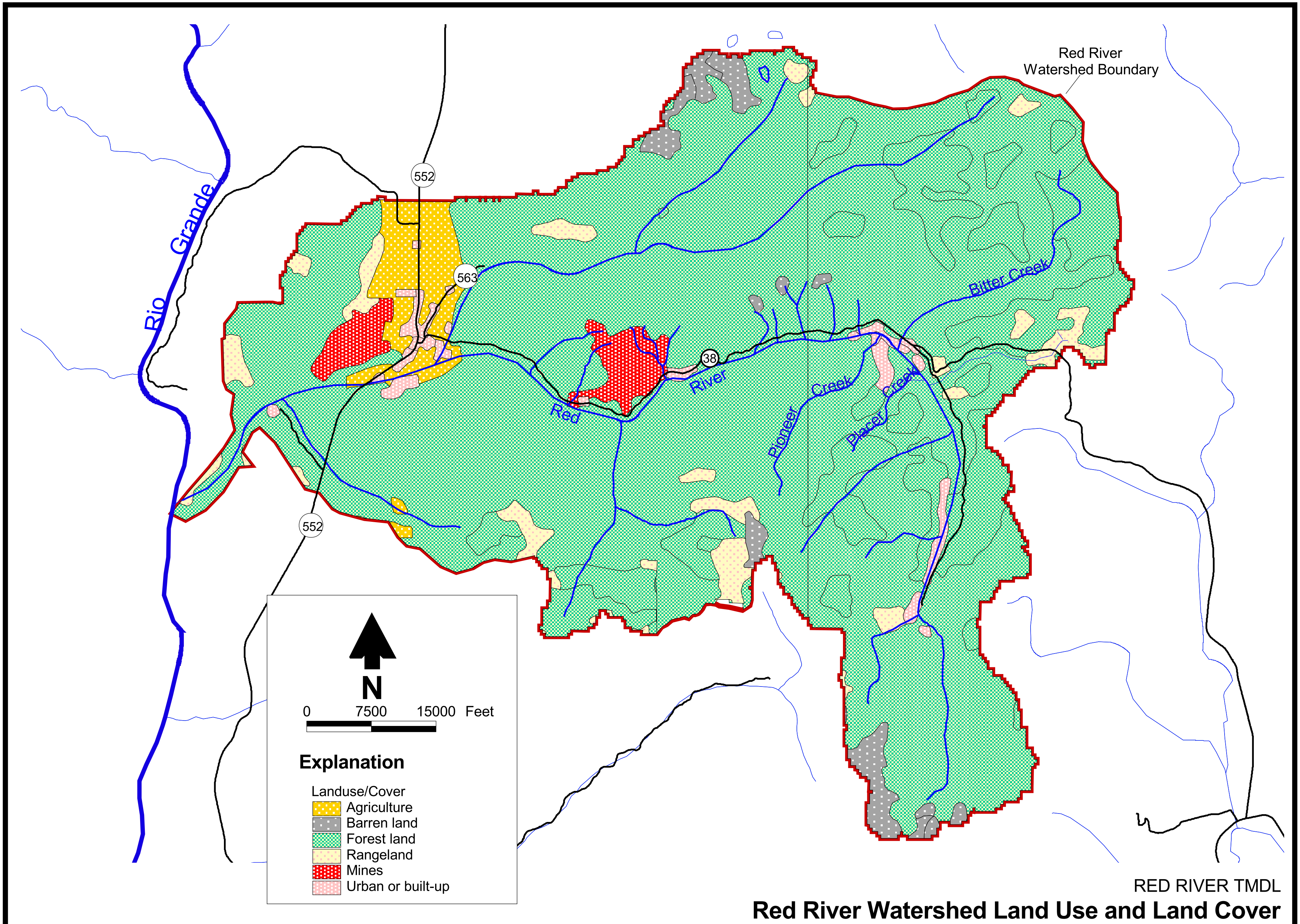

Red River Watershed Land Use and Land Cover

Figure 3

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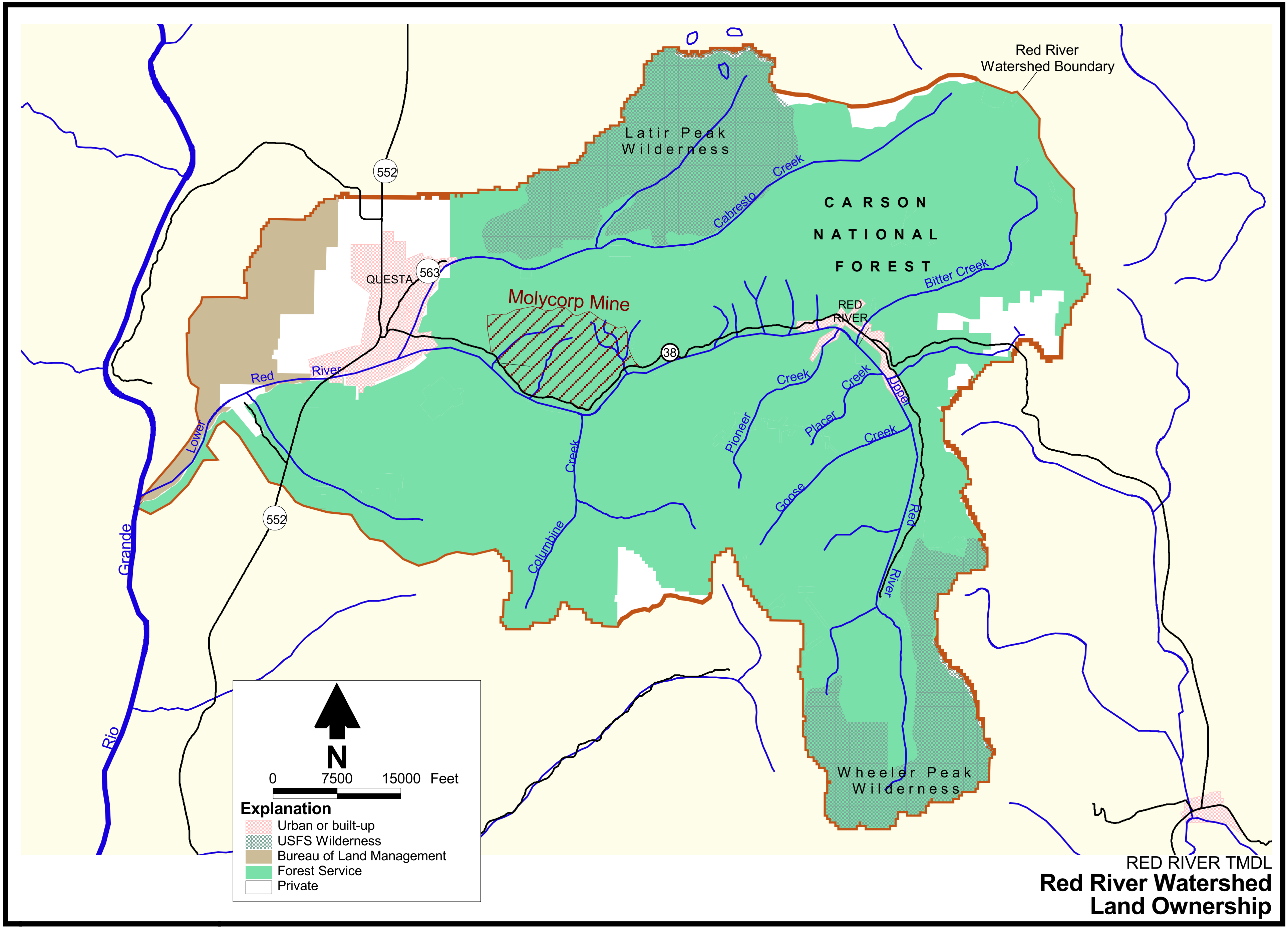

RED RIVER TMDL
Red River Watershed Land Ownership

Figure 4

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Alteration Scars

In the Red River drainage basin, there are approximately 25 distinct alteration scar areas that range in size from < 0.1 square kilometers (km^2) (<24.7 acres) to approximately 0.5 km^2 (123.6 acres). These areas collectively encompass approximately 600 acres, which amounts to 0.5% of the basin's area. Alteration scars are landforms characterized by steep slopes, a lack of soil, iron oxide staining and clay formation, rapid erosion, and common slumping and landsliding (Meyer and Leonardson, 1990). Runoff from the highly visible scars in the Red River valley contains high concentrations of iron oxides and clay minerals that turn the water orange, giving the Red River its name. The scars are thought to develop as a result of landslides and erosion in areas that become susceptible to mass wasting. Areas of faulting, fracturing, supergene alteration (weathering), and hydrothermal alteration are prone to landslides and scar development due to diminished shear strength of the affected rock mass (Meyer and Leonardson, 1990). In addition, anthropogenic activity in the Red River area aggravates scar development and the associated effects on water quality (RGI, 2000).

The scars are found mostly on the north side of the river and are aligned along two parallel, west-to-east trends (Meyer and Leonardson, 1990) that follow the trend of mineralization. The south-facing slopes have a lower density of stabilizing forest cover and other vegetation than the north-facing slopes (Meyer and Leonardson, 1990). Most of the scars are located east of the Molycorp Mine, but natural scars are also located within the mine's property.

A high pyrite content of 3 to 5% is common in scar areas, while a lower pyrite content of 1% or less is typical throughout most of the region. Samples taken from scar areas yield acidic-paste pH measurements as low as 0.8 (RGI, 2000) due to pyrite oxidation and acidic water generation. This indicates that weathering scars also contribute to acid rock drainage, dissolved constituent loads in ephemeral overland flow that follows the steep drainage systems, and acidic groundwater recharge that eventually seeps into the river (NMED, 1996). The flow and sulfate balance reported by Vail Engineering, Inc. (2000) indicates that significant sulfate loading can be attributed to natural sources such as alteration scars. The scars are also highly erosive and are the source of sediment and even mudflows that often wash across State Highway 38 and into the Red River during periods of heavy precipitation or snowmelt.

Fire Danger

Historically, fire played a very important role in the forests of the southwestern United States. In the ponderosa pine forests, low-intensity fires with return intervals of 4.8 to 11.9 years (Weaver, 1951 [cited in Wright, 1988]) thinned stands, eliminated young pines and/or mixed-conifer species, and maintained an open, park-like atmosphere with a ground cover of herbs and shrubs (Biswell, 1972; Cooper, 1960; Hall, 1976; and Weaver, 1947 [cited in Wright, 1988]). These low-intensity fires removed forest floor litter, preventing additional build up that could contribute to more catastrophic fires. However, fire suppression during the 20th century led to the declining health of many forests throughout the southwest, as the level of planting and amount of fuels increased. Fire ladders, a result of dense forests where branches occur on the tree stem from the ground into the live canopy, allow ground-fires to reach the uppermost crowns of trees. The results are larger, more destructive fires.

In spruce/fir forests, fire tends to occur at longer return intervals. Therefore, fires tend to be large, removing all trees and vegetation, and resetting the successional sequence. Pioneering species of trees and other plants quickly establish themselves in burned areas. Over time, the larger, dominant, trees take over the site.

Steep canyons, sensitive soils, and few access roads characterize the Red River Watershed. Both ponderosa pine and spruce/fir forests exist in the Red River Watershed. The last catastrophic fire occurred in the Red River Watershed sometime during the late 1890s to early 1900s, as evidenced by the condition of aspen stands, a pioneering tree species that establishes itself after a fire within the watershed (Thibedeau, 2001). As a result of fire suppression activities undertaken from the early 1900s to the present, fuel loading, which includes litter on the ground and standing trees, is great. Therefore, any fire that occurs on the Red River watershed would most likely be a severe, stand removal type fire. Once vegetation was removed, the nature of the soils and the steep terrain would likely result in severe erosion.

Molybdenum Mining

A molybdenum mine owned by Molycorp, Inc. is located north of the Red River between the Village of Questa and the Town of Red River (Figure 1). The mine occupies an almost three-square-mile area that is surrounded by the Carson National Forest (NMED, 1996). Mining operations at the property have been carried out in three phases (historic underground, open pit, and block-caving methods) since 1919 (URS, 2001).

Tailing material that was generated in the open pit mining process was transported in slurry form by a pipeline, and deposited in two tailings ponds that are located west of Questa (Figure 1). Also during pit development, a series of mine rock piles (approximately 320 million tons of material) were placed around the pit, covering parts of Capulin Canyon, Goathill Gulch, Sulphur Gulch, and Spring Gulch (URS, 2001). Some of these piles are visible from Highway 38 , which parallels the Red River.

The mine is currently in the process of developing closeout plans for the mining and tailings sites in accordance to the requirements of the New Mexico Mining Act. In addition, the United States Geological Survey (USGS) is conducting a background characterization study in the area.

Data Sources

The TMDL development included an analysis of the geology and soils of the basin, as well as a literature review and database analysis. Surface water and groundwater chemistry data for the major tributaries, outfalls, and aquifers within the Red River Basin were examined and subjected to rigorous quality assurance and quality control checks. These data include comprehensive surface water sampling and analyses in the Red River

Watershed conducted by the SWQB. Water quality sampling was conducted in 1999 through 2001 for the Red River in accordance with the EPA-approved Quality Assurance Project Plan for Water Quality Management Programs (NMED, 1998-2001). Other data sources that were reviewed are listed in Appendix A. To develop the stream bottom deposit TMDL, additional sediment sampling and biomonitoring was performed during 2001.

A geographic information system (GIS) database for use with ArcView software was created to synthesize the large amount of available data. Figure 1 was created with GIS to show the location of potential source areas with respect to significant drainage features such as major streams and their tributaries, ephemeral and perennial stream reaches, and reservoirs. Comparison of potential source areas with drainage patterns and water quality data shows where runoff from these sources enters the Red River.

ArcView was also used to determine the total and proportional areas of each source area within sub-basins of the Red River watershed. This information allowed the magnitude of sources to be estimated with respect to flow within each sub-basin. Quantitative flow analysis was determined through modeling, as described briefly in the Modeling section below and in more detail in Appendix B.

Surface water quality data in the study area was summarized and the distribution was depicted graphically. For example, in Appendix C water quality is illustrated with Stiff diagrams superimposed on the source area map. Distinct spatial variations in water quality were correlated to potential anthropogenic and/or natural sources. Groundwater quality was also included in this analysis.

The effects on the aquatic ecosystem from various pollutants, including aluminum, were evaluated. The evaluation was based primarily on literature reviews, consultation with governmental agencies, and analysis of existing data from the Red River Watershed for both macroinvertebrate and fish populations. The findings of this evaluation are described in Appendix D.

MODELING

The TMDLs for the impaired sections of the Red River were developed in part through two mathematical models: (1) a water balance and in-stream flow model and (2) an aluminum-loading model. The output of the flow model was used in the aluminum-loading model.

In general, the mass load of any dissolved constituent that enters a water body is calculated using the following equation:

Equation 1. $\quad \textit{Mass load (mass units / time)} = Q \times C$

Where Q = Discharge (volumetric units per unit time)
C = Average Concentration (mass per unit volume)

Water Balance and In-Stream Flow Model

Because of the rugged relief, streamflow in the Red River and its tributaries typically responds quickly to precipitation and runoff events along the entire length of the river. In general, the lowest flows occur in the winter and the highest occur in May and June when runoff peaks from snowmelt. Convective storm frequency, runoff, and irrigation diversions affect river flow during the summer months. In addition, groundwater discharge occurs along selected reaches of the river. Gaining reaches fed by springs far outnumber losing reaches.

A model was developed for the Red River Watershed that accounts for the various sources and sinks of water and the resulting in-stream flows (Appendix B). The watershed includes 2 current and 4 former USGS gage stations. Summary information for each of these stations is contained in Table 1. The information from these 6 stations was used to estimate the average daily streamflow at 18 TMDL flow model stations along the Red River for three key times of the year:

- May (high-flow conditions during snow runoff)
- August (average flow or rainstorm event conditions)
- October (base or low-flow conditions)

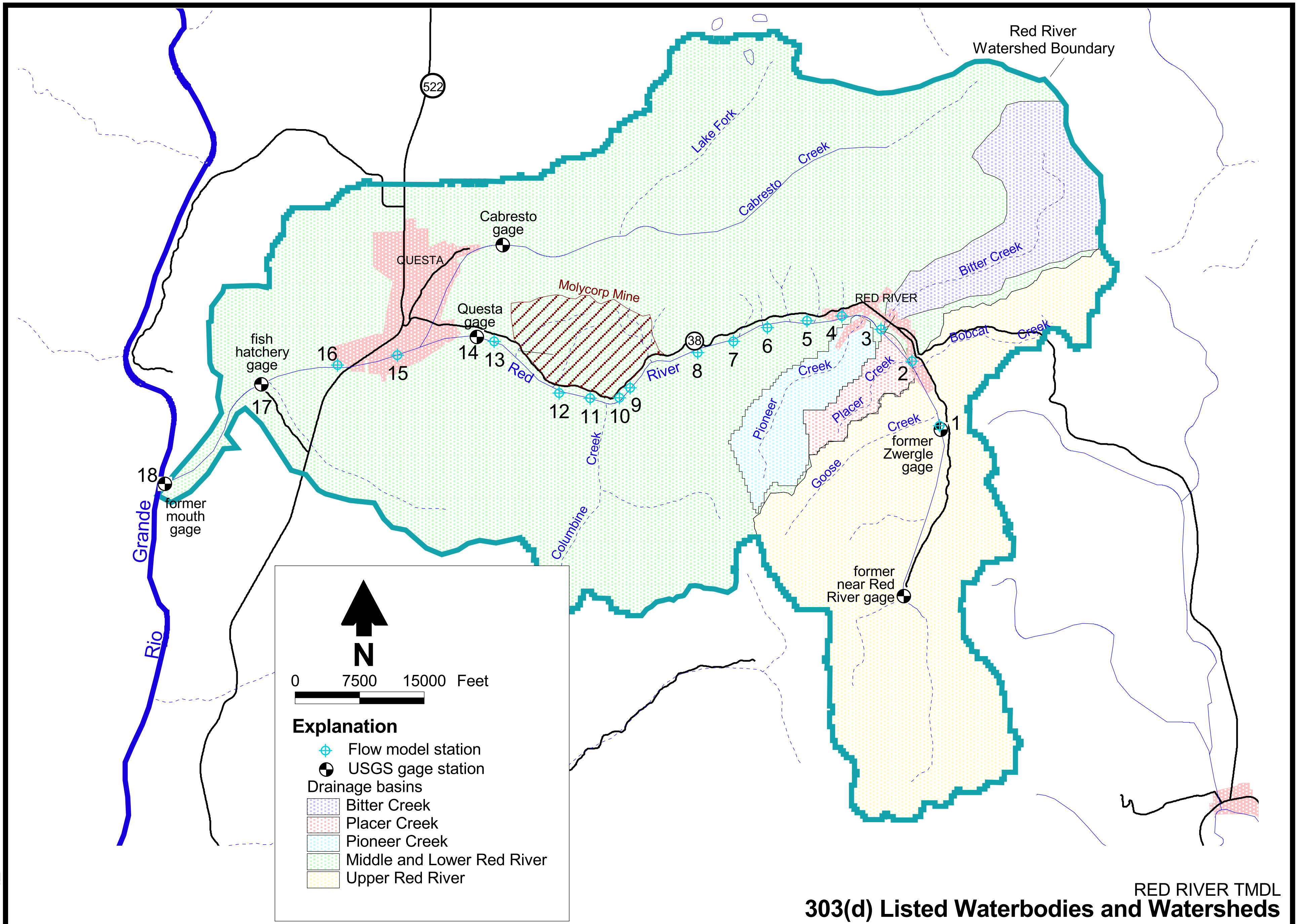
These months also correspond with the three intensive flow surveys that were conducted by the SWQB in 1999. Figure 5 shows the location of the listed drainage basins boundaries, major tributaries in the Red River Watershed, former and current USGS gage stations, and the 18 TMDL flow model stations.

Aluminum-Loading Model

The total aluminum-loading model is based on the chemistry and hydrology of rainfall that infiltrates into the groundwater, and flows beneath the surface to the Red River

Table 1: Summary of USGS Gage Stations in the Red River Watershed

Gage Name	Gage Number	Elevation (feet)	Drainage Area (m^2)	Approximate Distance from Mouth (miles)	Approximate Distance from Confluence of Upper Forks (miles)	Period of Record
Red River near Red River, New Mexico (Red River gage)	08264000	9,394.2	19.1	26.9	0.03	10/01/43 to 09/30/64 (sporadic)
Red River below Zwergle dam site, near Red River, New Mexico (Zwergle gage)	08264500	8,871.88	25.7	22.8	4.1	05/01/63 to 12/31/73
Red River near Questa, New Mexico (Questa gage)	08265000	7,451.92	113	8.8	18.1	10/01/24 to 09/30/25 01/01/30 to 12/31/41 03/01/42 **to present**
Cabresto Creek near Questa, New Mexico (Cabresto gage)	08266000	7,845	36.7	11	NA	10/01/43 to 09/30/96
Red River below fish hatchery, near Questa, New Mexico (fish hatchery gage)	08266820	7,087	185	3.3	23.6	08/09/78 **to present**
Red River at mouth, near Questa, New Mexico (mouth gage)	08267000	6,600	190	0.04	26.9	12/01/50 to 09/30/78



RED RIVER TMDL

303(d) Listed Waterbodies and Watersheds

Figure 5

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(Appendix C, Figure C1). As the water passes through mineralized rock and soil, leaching of the minerals increases the aluminum concentration in the form of dissolved aluminum hydroxysulfate ($AlOHSO_4$). The resulting acidic recharge also lowers the pH of the groundwater. The $AlOHSO_4$ remains dissolved until the pH of the groundwater increases to neutral values. Neutralization occurs in the hyporheic zone (Appendix C, Figure C1) of the Red River as a result of groundwater reaction with sediments, surface water, plants, and other biota. As this higher pH water enters the hyporheic zone, the pH of the groundwater rises and gibbsite ($Al(OH)_3$) precipitates out of solution and forms a white coating on the stream bottom near groundwater seep locations. Gibbsite coatings have been observed in similar settings elsewhere (Theobold et al., 1963; Nordstrom, 1982). The coating is periodically scoured off the bottom of the river by high-flow events and temporarily increases the sediment loading in the river.

The aluminum mass loading along selected reaches of the river was calculated based on the dissolved aluminum concentrations determined by previous sampling and analysis of the seeps and groundwater monitoring wells located along the north side of the Red River (seeps, well locations, and flow model stations 1 through 14 are shown in Figure 6). The total aluminum concentrations from all sampled seeps between each flow station were averaged. The product of the averaged aluminum value and the modeled flows of the seeps along the same reach yields the total aluminum loading in pounds per day (lb/day) that flows into the Red River (Equation 1). These calculations are contained in Appendix C.

This calculation assumes that aluminum concentrations in the seeps do not vary seasonally, and that loading is proportional to the flow from the seep (Appendix C). However, the water quality data collected by the SWQB indicate that aluminum concentrations are highest during runoff (Appendix C). Therefore, the highest stream flows and measured aluminum concentrations, which occurred in May, were used to determine the loading.

In summary, downstream loading model simulations were performed to calculate the TMDLs using a high-flow scenario. The model scenario assumes that mass loading is highest under high-flow conditions, and is applicable to constituents such as aluminum, sediments, and turbidity that increase during runoff events. The use of a high-flow scenario as the basis for the Red River Watershed TMDLs provides a conservative approach with an optimal MOS and allowance for future growth.

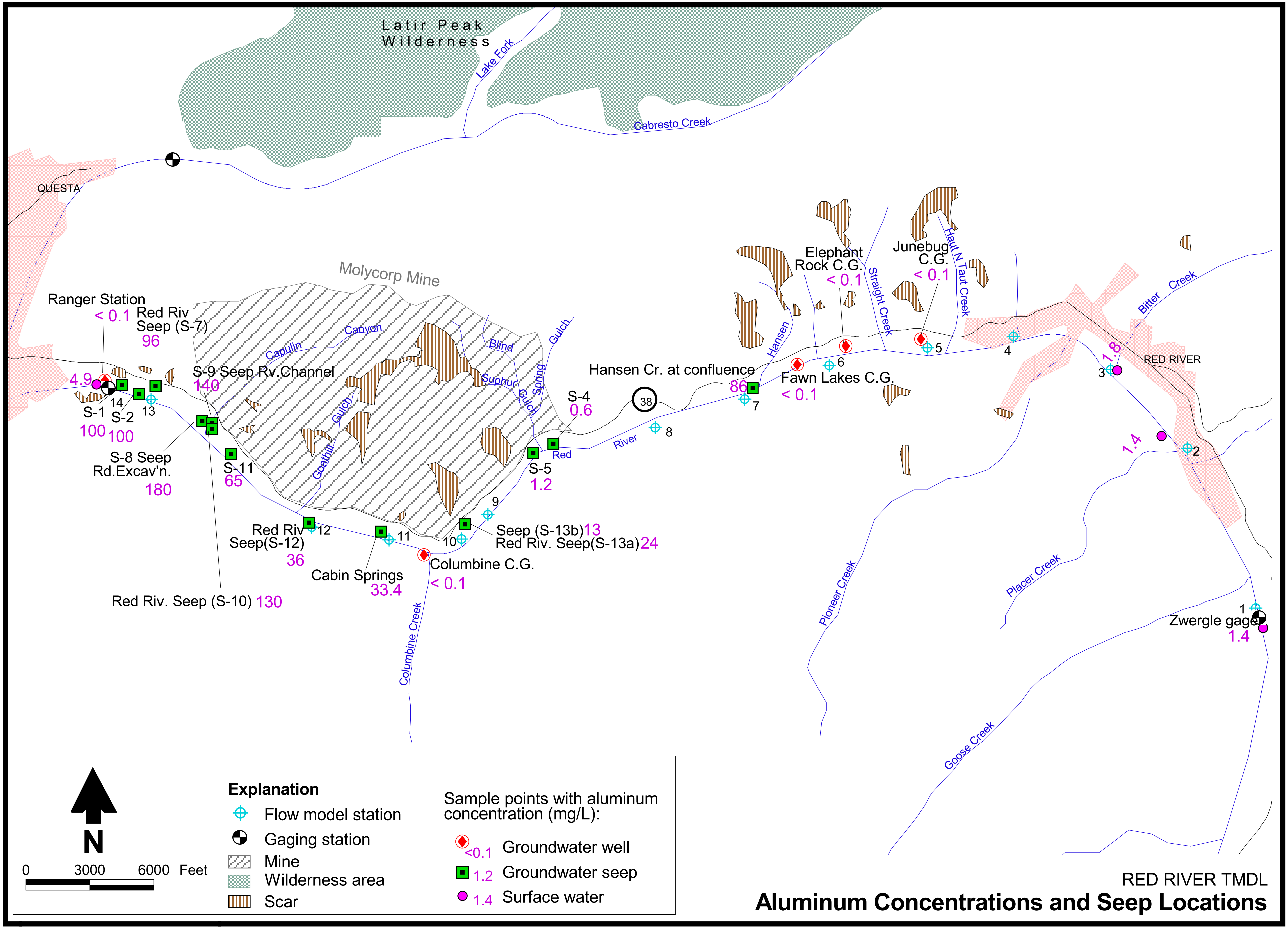

Figure 6

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NUMERIC WATER QUALITY TARGETS

Numeric water quality standards are established according to categories of designated uses that a water body is capable of supporting given its geographic characteristics and historical uses. The New Mexico 2000-2002 303(d) list (NMED, 2001a) indicates beneficial uses that are not fully supported or that are threatened in the Red River watershed. These include the following:

- High quality coldwater fishery
- Coldwater fishery
- Livestock watering
- Irrigation

The HQCWF and CWF uses are subject to the most stringent numeric water quality requirements under both federal guidance and state regulations (NMWQCC, 2001). Previous investigations and data analyses conducted by the SWQB determined that numeric water quality targets were needed for aluminum, stream bottom deposits, and turbidity along designated reaches and tributaries of the Red River.

Overall, the target values for the TMDLs developed for these water bodies were determined based on (1) the presence of numeric criteria, (2) the degree of experience in applying the indicator and (3) the ability to easily monitor and produce quantifiable and reproducible results. For metals (aluminum) and turbidity, target values are based on numeric criteria. Target values for stream bottom deposits are based on assessment protocols that interpret narrative criteria.

Target Aluminum Loads

According to the New Mexico water quality standards (20.6.4.900.J NMAC) the state's standard leading to an assessment of use impairment for all subcategories of fisheries is:

- Chronic dissolved aluminum shall not exceed 87 micrograms per liter (μg/L)
- Acute dissolved aluminum shall not exceed 750 μg/L

Water resources designated for use as fisheries that exceed these limits are considered to be impaired.

Exceedances of the numeric criteria for both chronic and acute aluminum were detected in the Red River through water quality sampling conducted by the SWQB. As a result of multiple exceedances of the chronic aluminum standard in samples collected during the spring of 1999, the main stem of the Red River and the Cabresto Creek tributary were included in the 2000-2002 NM 303(d) list. Waters in Bitter and Placer Creeks also exceeded the acute aluminum standard and these tributaries were also placed on the list.

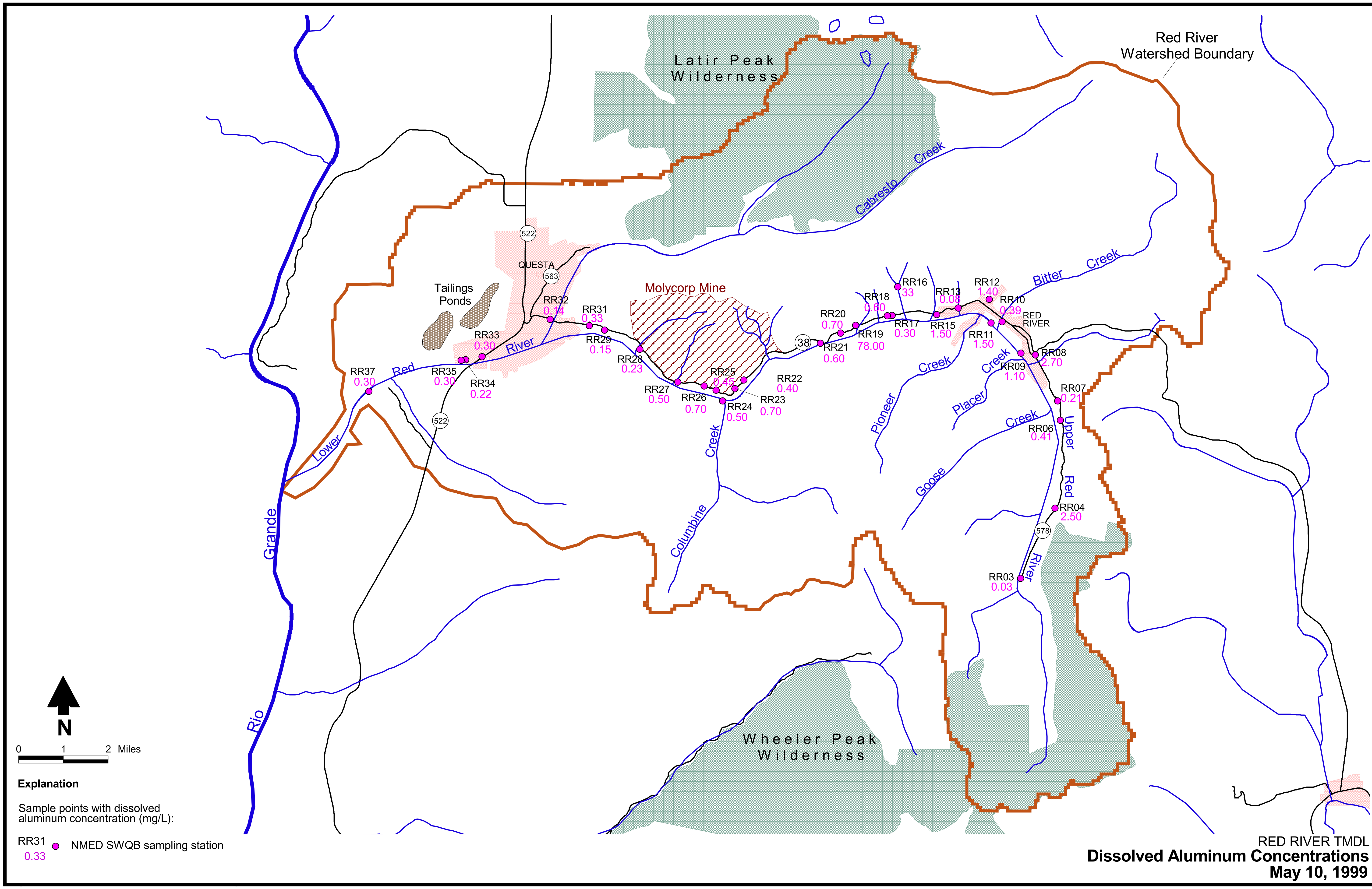
These TMDLs were developed to address impairments due to chronic and acute aluminum toxicity. Numeric targets were developed on the basis of a bioassessment for the middle reach of the Red River, where very high loads of aluminum occur. As discussed in the Background section, some of this appears to be a result of naturally occurring aluminum loads from the weathering of alteration scars at heads of tributaries. The degree to which background metal and sediment loads may have increased as a result of human activities in the watershed is not known. A future study to be conducted by the USGS may provide more information on natural and enhanced background loads to the Red River (Nordstrom, 2000).

Aluminum concentrations are generally less than 1 milligram per liter (mg/L) along the course of the Red River (Figure 7), probably because the surface water is saturated with respect to $Al(OH)_3$ (Appendix C). Hence, precipitation of this compound provides an upper limit on aluminum concentrations despite progressive aluminum loading from tributaries and seeps that carry higher aluminum concentrations.

Specific biological impacts associated with aluminum exceedances of water quality standards have not been identified to date. Dissolved aluminum concentrations do not seem to directly correlate with impairment of CWFs. An internal reference standard was developed with respect to the mass loading of total aluminum in Bitter Creek and the Middle Red River (from the confluence of Placer Creek to the confluence of Columbine Creek). The standard was established by empirical comparison of measured total aluminum loads and observed biological responses in this reach. This standard recognizes the relatively high natural background loading that occurs along these segments due to the weathering of alteration scars located on the north side of the river.

To develop this biologically based standard, the calculated aluminum mass loads for biomonitoring sites along the central reach of the Red River were plotted against the total number of trout in samples collected over several years at the sites (Figure 8). This comparison shows lower fish densities at sites with higher aluminum mass loads. Comparisons of fish densities at stations 5 and 6 to those at station 7 (Figure 8) indicate an adverse reaction to the high loads at station 7, resulting in a lower fish density downstream. The lowest trout biomass and density occurred at the site near the Questa Ranger Station (station 14, Figure 8). The model calculated a maximum aluminum loading just upstream of this biological sampling location of 1,312 lb/day (Appendix C). Benthic macroinvertebrate numbers and diversity show similar responses to aluminum loads (Appendix C).

At the biological monitoring sites downstream of the Molycorp mill (stations 10 and 12, Figure 8), there is an increase in trout biomass and numbers. The recovery of trout populations at these stations is attributed to lower aluminum loads. Moreover, the higher fish density along this reach is due to increases in the number of brown trout, a species that maintains its populations in the Red River through natural reproduction. Also, stations 10 and 12 are located upstream and downstream of Columbine Creek, respectively, and fish densities in the Red River may be influenced by an influx of fish downstream from this tributary. The Columbine Creek watershed does not receive acidic seepage from the scar areas and provides a good coldwater fishery habitat. However, fish



Red River Watershed Boundary
Latir Peak Wilderness
Wheeler Peak Wilderness
Molycorp Mine
Tailings Ponds
QUESTA
RED RIVER
Cabresto Creek
Bitter Creek
Pioneer Creek
Placer Creek
Goose Creek
Columbine Creek
Upper Red River
Lower Red River
Rio Grande
522
563
38
578
RR03 0.03
RR04 2.50
RR06 0.41
RR07 0.21
RR08 2.70
RR09 1.10
RR10 0.39
RR11 1.50
RR12 1.40
RR13 0.08
RR15 1.50
RR16 33
RR17 0.30
RR18 0.60
RR19 78.00
RR20 0.70
RR21 0.60
RR22 0.40
RR23 0.70
RR24 0.50
RR25 0.45
RR26 0.70
RR27 0.50
RR28 0.23
RR29 0.15
RR31 0.33
RR32 0.14
RR33 0.30
RR34 0.22
RR35 0.30
RR37 0.30
N
0 1 2 Miles
Explanation
Sample points with dissolved aluminum concentration (mg/L):
RR31 0.33 NMED SWQB sampling station
RED RIVER TMDL
Dissolved Aluminum Concentrations
May 10, 1999
1/4/02

Figure 7

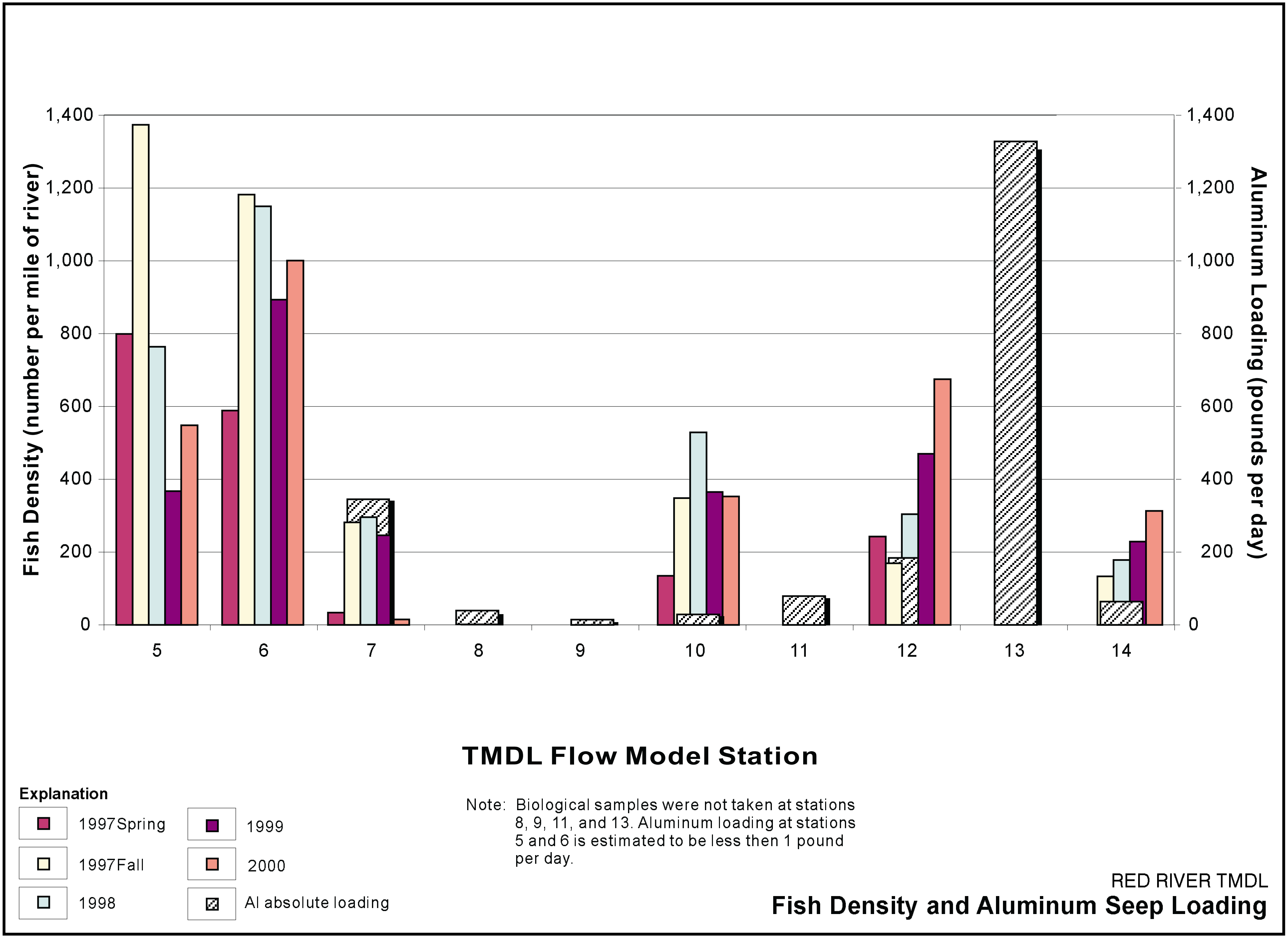


Figure 8

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biomass in the Red River immediately upstream (station 10) and immediately downstream (station 12) is similar to that estimated in Columbine Creek.

Total aluminum mass loads greater than 300 lb/day seem to produce an observed decline in trout densities in this portion of the Red River. However, loads of approximately 30 lbs/day at station 10 and up to 195 lbs/day at station 12 allowed a trout density recovery despite the decrease in the population seen upstream (station 7). A target loading for Bitter Creek and the Middle Red River was chosen based on these empirical results. Using the positive response at 195 lbs/day and applying an implicit margin of safety, a conservative target load capacity of 50 lb/day was selected for Bitter Creek and for individual load inputs (tributaries and seepage) in the Middle Red River (Appendix C, Table C5).

For the remaining segments of the main stem of Red River (Upper and Lower Red River) and the Cabresto Creek tributary the dissolved aluminum standard of 87 μg/L with respect to chronic toxicity was used as the numeric target. For Placer Creek the dissolved aluminum acute standard of 750 μg/L was used as the target because this reach was listed for exceedances of that standard. The target aluminum loads for each of the listed reaches were calculated using Equation 2.

Equation 2. *Flow (million gallons per day [mgd]) x standard (milligrams per liter [mg/L]) x 8.34 (conversion factor) = Target loading capacity*

Table 2 shows the resulting target loads that were derived from this equation.

Table 2: Calculation of Target Loads for Metals (Aluminum) TMDL

Location	**Flow + (mgd)**	**Standard Metals Dissolved Aluminum (mg/L)**	**Conversion Factor***	**Target Load Capacity (lbs/day)**
Tributaries				
Placer Creek	1.6	0.750 (acute)	8.34	10.0
Bitter Creek	6.7	NA	8.34	50.0 (Based on biological assessment)
Cabresto Creek	21.8	0.087 (chronic)	8.34	15.8
Main Stem of the Red River				
Upper Red River	32.0	0.087 (chronic)	8.34	23.2
Middle Red River	59.3	NA	8.34	588.7 (Based on biological assessment)
Lower Red River	112.7	0.087 (chronic)	8.34	81.8

+ Flow values were estimated from Red River Watershed flow model for May (Appendix B).
* See Appendix E for conversion factor derivation.

Target Stream Bottom Deposit Loads

The applicable narrative standard for bottom deposits, as found in the New Mexico standards (20.6.4.12.A NMAC), states:

> Bottom Deposits: Surface waters of the State shall be free of water contaminants from other than natural causes that will settle and damage or impair the normal growth, function, or reproduction of aquatic life or significantly alter the physical or chemical properties of the bottom.

Exceedances of this standard result in an assessment of use impairment. There are no applicable numeric criteria for bottom deposits. The SWQB has developed a protocol to assess physical and biological impairment using the narrative criteria for stream bottom deposits (NMED, 2001b). The SWQB Protocol for the Assessment of Stream Bottom Deposits uses these methods coupled with a biological assessment using EPA's Rapid Bioassessment Protocol (Plafkin et al., 1989; Barbour et al., 1999) to assess possible stream bottom impairment.

To properly assess a study site or stream reach for impairment(s) due to stream bottom deposits, a proper reference site (i.e., one with similar conditions) must be selected and classified for comparison. Once this is accomplished, selected indicators such as the percentage of fines, embeddedness, and biological integrity can be measured and compared between the two sites. Columbine Creek was selected by the SWQB as the reference site for Bitter Creek. Data collected from the reference and study site and the stream bottom deposit assessment are available in Appendix F.

In the listed reaches that result in non-support or partial support, a TMDL must be developed. The site may be evaluated as fully supporting regardless of the percent fines at the reference site, if the percentage of fines at the study site is 30% or less. This assumption is derived from the study by Relyea et al. (2000), which concluded that changes to the macroinvertebrate community occur when the site has 20 to 35% fines. Therefore, target loading was chosen to be 30% fines, as shown in Table 3.

Table 3: Calculation of Target Loads for Stream Bottom Deposits TMDL

Location	Stream Bottom Deposits (% fines)	Target Load Capacity (% fines)
Bitter Creek	30	30

Target Turbidity Loads

According to New Mexico standards (20.6.4.12 NMAC):

> Turbidity attributable to other than natural causes shall not reduce light transmission to the point that the normal growth, function, or reproduction of aquatic life is impaired or that will cause substantial visible contrast with the natural appearance of the water.

The State's standard leading to an assessment of use impairment is the numeric criteria stating that "turbidity shall not exceed 25 NTU [nephelometric turbidity units]" for the appropriate designated use of a HQCWF. Pioneer Creek falls into standard segment 20.6.4.123 (formerly 2120), which is defined as:

> Rio Grande Basin - The Red river upstream of the mouth of Placer creek, **all tributaries to the Red river,** and all other perennial reaches of tributaries to the Rio Grande in Taos and Rio Arriba counties unless included in other segments.

The target load for turbidity is calculated based on flow, current water quality standards, and a conversion factor, 8.34, that is used to convert mg/L to lbs/day (see Appendix E for conversion factor derivation). The target loads (TMDLs) predicted to attain standards were calculated using Equation 2 (shown above) and are shown in Table 4.

Table 4: Calculation of Target Loads for Turbidity TMDL

Location	Flow + (mgd)	Standard* TSS (mg/L)	Conversion Factor	Target Load Capacity (lb/day)
Pioneer Creek	3.6	22.0	8.34	660.5

+Because there is no USGS station on this reach, flow value was estimated from Red River Watershed flow model for May (Appendix B).

*This value is calculated using the relationship established between turbidity and total suspended solids (TSS) - (y = 0.7848x + 2.4248) R^2 = 0.5979 (See Appendix G). The turbidity standard is 25 NTU so the corresponding TSS value is 22.0 mg/L.

TMDL AND ALLOCATION OF POLLUTION LOADS

The biological monitoring data (fish and benthic macroinvertebrate population data [Appendix D]) and loading analysis presented in the Numeric Water Quality Targets section support the hypothesis that the primary causes of impairment in certain Red River segments are aluminum precipitation, stream bottom sedimentation, and turbidity. Therefore, this study focused on the calculation of TMDLs for aluminum, sediments, and turbidity in selected segments in the watershed.

The TMDLs and associated WLAs and LAs were developed based on the evaluation of the model output, which provided the optimal distribution of loads that will still allow support for designated uses. The trends in biological data suggest three logical divisions for the Red River. The first is the area upstream of the zone of influence on water quality attributable to the alteration scar areas (upstream of the Bitter Creek confluence). The second includes the zone of scarring and the influences of the canyon on the river geomorphology (from the Bitter Creek confluence to downstream of the Ranger Station) (Figure 6). The third is downstream of these influences to the confluence of the Red River with the Rio Grande.

Non-impaired, tributary, and upstream sources of pollutants to the Red River must be considered because their WLAs and LAs contribute to the TMDL. Moreover, these sources must also be considered in the TMDL to provide an adequate MOS so that future growth and local disturbances in the watershed will pose no risk of impairment to the downstream segments of the Red River.

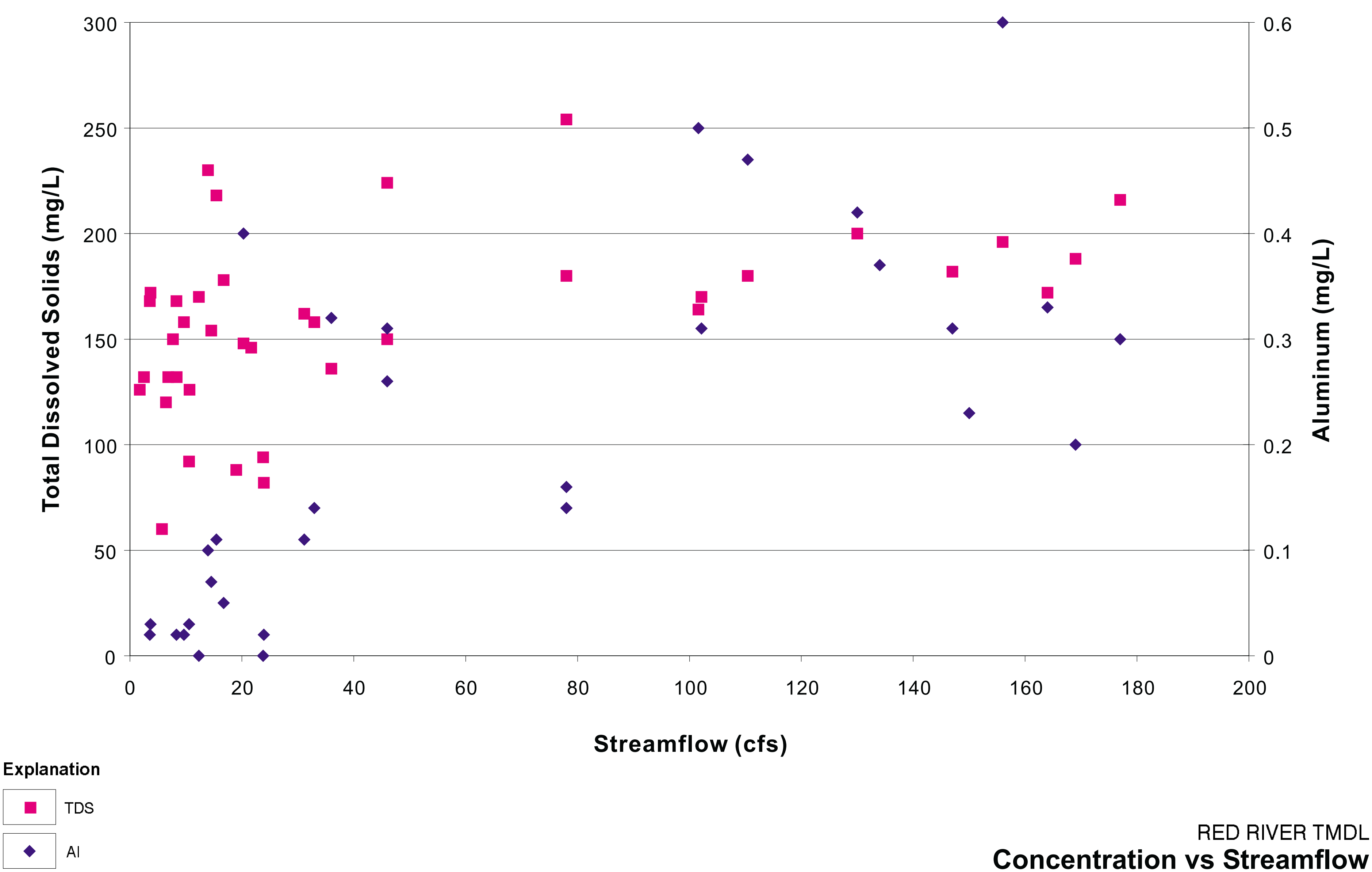
The TMDL was calculated according to the following standard equation:

$$\textit{Equation 3.} \quad TMDL = WLA + LA + MOS$$

The MOS is a combination of implicit and explicit allowances. The implicit MOS is based on the selection of conservative values in the TMDL calculations. For example, the use of high-flow (May) parameters in the calculation is considered to be a conservative estimate of the TMDL because loads are usually highest during this period. Furthermore, pollutant concentrations are higher than average and may peak during high flow events (Figure 9).

Aluminum Total Maximum Daily Load

The measured dissolved loads are summarized in Table 5. These loads were calculated using Equation 2 with the highest aluminum concentration collected at each site in May 1999 substituted for the standard. Results of the aluminum model for each of the flow stations are provided in Appendix C; these results were used to construct Figure 8.



RED RIVER TMDL
Concentration vs Streamflow

Figure 9

12-28-01 JN 9253

Table 5: Measured Loads for Nonpoint Sources, Red River and Tributaries

Location	Flow + (mgd)	Measured Concentration (mg/L)*	Conversion Factor	Total Aluminum Loading (lb/day)
Tributaries				
Placer Creek	1.6	1.4	8.34	18.7
Bitter Creek	6.7	1.8	8.34	100.6
Cabresto Creek	21.8	0.29	8.34	52.7
Main stem of the Red River				
Upper Red River	32.0	1.4 (station 1)	8.34	373.6
Middle Red River	59.3	NA (station 10)	8.34	1,190.9 **
Lower Red River	112.7	8.0 (station 17)	8.34	7,519.3

+Flow values were estimated from Red River Watershed flow model for May (Appendix B).
*Peak concentrations from May 1999 were used as conservative values (See Appendix C).
**Total aluminum loading determined in Appendix C, Table C6.

Waste Load Allocation (WLA)

There are three point sources on the Red River. From upstream to downstream they are the wastewater treatment plant (WWTP) for the Town of Red River, the Molycorp Mine, and the Red River Fish Hatchery. The outfall locations for these sources are shown on Figure 1. The Red River WWTP and the fish hatchery have one outfall each. The Molycorp Mine has four permitted outfalls; however, only outfall 2 has continuous discharge (from the tailings interceptor system) and was considered in the TMDL calculation. The other three outfalls are intermittent, containing process water and storm water. Monitoring records indicate no discharges from these outfalls. As an additional BMP in the Molycorp Mine's recently renewed NPDES permit, they are required to "install seepage interception systems to prevent discharges of process related groundwater to the Red River at Spring 13 and Spring 39" (EPA, 2000). The locations of Springs 13 and 39 are shown in Figure 1. Current load estimates (pre-BMP installation) for these springs are shown in Table 6.

Table 6: Measured Load Estimates for Molycorp Mine Springs 13 and 39

Location	Flow + (mgd)	Measured Concentration (mg/L)*	Conversion Factor	Total Aluminum Loading (lb/day)
Molycorp Mine Spring 13	0.07	85.0	8.34	49.6
Molycorp Mine Spring 39	0.05	15.0	8.34	6.3

+Flow values set at minimum pumping rate required by NPDES permit (EPA, 2000).
*Values are the average 2001 concentrations given by Martinez, 2002.

The monthly average discharge limits for total aluminum at the Red River WWTP, the Molycorp Mine outfalls, and the fish hatchery are listed in Table 7. The current permit for the fish hatchery does not include a discharge limit for total aluminum. The maximum aluminum loading under the Molycorp permit is 0.25 lb/day from outfall 2 during the first two years of the recently renewed five-year permit (2001 through 2002). The total aluminum discharge limit for the Red River WWTP is also phased, with the highest limit being 2.63 lb/day during the first two years (2001 through 2002).

Table 7: NPDES Permitted Point Source Discharge Limits for Total Aluminum

Outfall	Listed Reach	Discharge Limit (lb/day Al)
Red River WWTP #1	Middle Red River	2.63
Molycorp Mine Spring 39	Lower Red River	0.04 *
Molycorp Mine Spring 13	Lower Red River	0.05 *
Molycorp Mine #2	Lower Red River	0.25
Fish Hatchery	Lower Red River	no limit specified

*Discharge limits were calculated from the chronic aluminum standard (0.087 mg/L) and the minimum pumping rate that was shown in Table 6.

The discharge limit for each of the permitted point sources is well below the target loads for aluminum, and impairment of the Red River from these sources is assumed to be negligible. Therefore, the WLAs for the Red River will be the discharge limits as set in the National Pollutant Discharge Elimination System (NPDES) permits.

Load Allocation (LA)

A comparison of Tables 5 and 7 shows that NPS loading in the Red River is the major source of total aluminum to the river. Total aluminum loading from natural seeps and base flow to the river ranges from less than 1 lb/day to more than 7,500 lb/day (Table 5, and Appendix C, Table C6). The main areas that contribute to loading are near flow model stations 7 and 11 through 13 (Figure 6). The estimated loads for each of these sites are given in Appendix C. Impairments from aluminum loading appear to be localized and are not cumulative (Figure 8). Therefore, the numeric standards developed for the middle reach of the Red River are applied to individual springs and tributaries along this reach that contribute to aluminum precipitation.

The LAs for the listed reaches of the Red River that correspond to the nonpoint sources were calculated as follows:

Equation 4. $LA = TMDL - MOS - WLA \text{ (for the appropriate point source)}$

If the target loading is 81.8 lb/day for the Lower Red River, then the MOS is 81.8 lb/day x 0.20 = 16.36 lb/day (using an MOS of 20%, as described in the Margin of Safety section, below). As an example, the load allocation for the Lower Red River using the Molycorp Mine discharge limit of 0.34 lb/day, is:

$$LA = 81.8 \text{ lb/day} - 16.36 \text{ lb/day} - 0.34 \text{ lb/day} = 65.1 \text{ lb/day}$$

Load allocations for the Red River Watershed are given in Table 8.

Table 8: TMDLs for the Red River and Impacted Tributaries

	WLA (lb/day Al)	LA (lb/day Al)	MOS (lb/day Al)	TMDL (lb/day Al)
Tributaries				
Placer Creek	0	8.0	2.0	10.0
Bitter Creek	0	40.0	10.0	50.0
Cabresto Creek	0	12.6	3.2	15.8
Main stem of the Red River				
Upper Red River	0	18.6	4.6	23.2
Middle Red River	2.63	468.33	117.74	588.7
Lower Red River	0.34	65.1	16.36	81.8

The load reductions that would be necessary to meet the target loads were calculated to be the difference between the target load (Table 2) and the measured load (Table 5). These results are shown in Table 9.

Table 9: Calculation of Load Reduction

Location	Target Load (lb/day Al)	Measured Load (lb/day Al)	Load Reduction (lb/day Al)
Tributaries			
Placer Creek	10.0	18.7	8.7
Bitter Creek	50.0	100.6	50.6
Cabresto Creek	15.8	52.7	36.9
Main stem of the Red River			
Upper Red River	23.2	373.6	350.4
Middle Red River	588.7	1,190.9	602.2
Lower Red River	81.8	7,519.3	7,437.5

Stream Bottom Deposits Total Maximum Daily Load

Based on the Protocol for the Assessment for Bottom Deposits, results from the benthic macroinvertebrate survey conducted in September 2001 indicate the benthic community for Bitter Creek was moderately impaired when compared to the reference station located on Columbine Creek.

The biological assessment for Bitter Creek scored 45% (moderately impaired) when compared to the reference site on Columbine Creek (Table 10). The reduction in biological score appears to correlate with an increase in percent fines at this site. At the Bitter Creek site, stream bottom sediment contained 81% fines while the reference site contained 4% fines. No embeddedness data was collected at the study site.

Table 10: Physical and Biological Assessment

Location	Biological Score as % of Reference	Pebble Count as % fines	Embeddedness as % fines	Final Assessment
Columbine Creek Reference	100%	4%	34%	Full Support Reference
Bitter Creek	45%	81%	Data not collected	Partial Support

To calculate the LA, the WLA and MOS were subtracted from the target capacity (TMDL) following Equation 3 (shown above). Results are presented in Table 11.

Table 11: Calculation of TMDL for Stream Bottom Deposits

Location	WLA (% fines)	LA (% fines)	MOS (% fines)	TMDL (% fines)
Bitter Creek	0	22.5	7.5	30

Achieving the target load for stream bottom deposits (SBDs) for Bitter Creek would require a load reduction of approximately 72% (Table 12). For example, using the measured percent fines value of 81% for Bitter Creek (Table 10) and a NPS target load of 22.5% fines (TMDL – MOS), a 72% overall reduction in sediment is calculated as necessary to achieve the target.

Table 12: Calculation of Load Reductions

Location	Target Load (% fines)	Measured Load (% fines)	Load Reduction (% reduction)
Bitter Creek	30	81	72

Turbidity Total Maximum Daily Load

The current measured loads were calculated using Equation 2. Typically, the geometric mean of all TSS measurements that exceeded the calculated limit of 22 mg/L (Table 4) would be substituted for the standard in Equation 2. In this case, only one measurement exceeded 22 mg/L, so this measurement was used in place of the standard in the equation (see Appendix G for field measurements). The conversion factor of 8.34 was used. Results are presented in Table 13.

Table 13: Calculation of Measured Loads

Location	Flow + (mgd)	Field Measurements (mg/L)	Conversion Factor	Measured Load (lb/day)
Pioneer Creek	3.6	35	8.34	1,051

+Because there is no USGS station on this reach, the flow value was estimated from Red River Watershed flow model for May (Appendix B).

It was not possible to calculate background loads in this watershed because a reference reach with similar stream channel morphology and flow was not identified. It is assumed that a portion of the turbidity load allocation consists of natural background loads. In future water quality surveys, finding a suitable reference reach will be a priority.

Waste Load Allocation

There are no point source contributions associated with the turbidity TMDL. Consequently, the WLA is zero.

Load Allocation

To calculate the LA, the WLA and MOS were subtracted from the target capacity (TMDL) following Equation 3 (shown above). Results are presented in Table 14.

Table 14: Calculation of TMDL for Turbidity

Location	WLA (lb/day)	LA (lb/day)	MOS (lb/day)	TMDL (lb/day)
Pioneer Creek	0	561.4	99.1	660.5

The turbidity load reduction necessary to meet the target loads were calculated to be the difference between the target load (Table 14) and the measured load (Table 13). Results are shown in Table 15 (Calculation of Load Reductions). For example, for Pioneer Creek, achieving the target load of 660.5 lbs/day would require a load reduction of 390.5 lbs/day. Achieving the target load for turbidity on Pioneer Creek would require a load reduction of approximately 37%.

Table 15: Calculation of Load Reductions

Location	Target Load (lb/day)	Measured Load (lb/day)	Load Reduction (lb/day)
Pioneer Creek	660.5	1051	390.5

Identification and Description of Pollutant Sources

A variety of potential point and nonpoint sources of pollutants and sediments are located in the watershed (Figure 1). The area includes three point-source dischargers regulated through NPDES permits issued by the EPA:

Hansen Creek scar area

- The Town of Red River wastewater treatment plant discharges its treated effluent near the Elephant Rock Campground (NPDES Permit NM0024899).

- The Red River Fish Hatchery is located near the confluence of the Rio Grande. The hatchery discharges return water from its raceways (NPDES Permit NM0030147).

- A large molybdenum (Molycorp) mine operates along the middle 10 miles of the river. The mill tailings from the mine are deposited in tailing ponds located just west of the town of Questa. There are four permitted discharge points, but only one has continual discharge of collected tailing dam seepage (NPDES Permit NM0022306).

Based on the relatively low allowable discharge limits and compliance monitoring, it seems likely that the NPS areas within the watershed are the primary cause of impacts to the Red River. The following nonpoint sources have been identified:

- Natural alteration scars are located along the river from the Molycorp Mine upstream to the town of Red River (Figure 1). The scar areas contribute to decreased water quality in the Red River under two conditions. During runoff events, large amounts of sediment and acidic runoff are released from these areas, often coloring the river a mustard yellow. The scar areas also release acid rock drainage that enters the Red River as groundwater seepage. This groundwater seepage has low pH, elevated aluminum content and a suite of other metals, and appears to be a major factor in the impairment of the river.

- There are also several scar areas located within the Molycorp Mine property land holdings that contribute to NPS pollution. These areas are adjacent to mineralized rocks exposed and/or disturbed during the mining process. The *Molycorp Questa Mine Site-Wide Comprehensive Hydrologic Characterization Report* (URS, 2001) describes the potential NPS pollution source areas at the Molycorp Mine.

- Road maintenance along Highway 38 has led to changes in the course of the Red River, resulting in increased sediment erosion in certain areas.

- The Red River Ski Area and the Town of Red River are located upstream of the mine; the township stretches for 1.5 miles along the river downstream from Placer Creek. The ski area is developed on mineralized rock and soil.

- Numerous logging and other access roads have been constructed on the steep slopes that adjoin the river and its tributaries. Some road cuts expose mineralized bedrock and acidic scar debris. In addition, dwellings with individual septic systems are also located along these roads.

- Cabresto Creek enters the Red River at the Village of Questa and passes through numerous agricultural operations.

- The Village of Questa has several unlined sewage lagoons located near the Red River.

Linkage of Water Quality and Pollutant Sources

Where available data are incomplete or where the level of uncertainty in the characterization of sources is large, the recommended approach to TMDLs requires the development of allocations based on estimates utilizing the best available information.

SWQB fieldwork includes an assessment of the potential sources of impairment (NMED, 1999). The Pollutant Source(s) Documentation Protocol, included as Appendix H, provides an approach for a visual analysis of a pollutant source along an impaired reach. Although this procedure is subjective, SWQB feels that it provides the best available information for the identification of potential sources of impairment in this watershed. Accordingly, Table 16 (Pollutant Source Summary) identifies and quantifies potential sources of nonpoint source impairments along each reach as determined by field reconnaissance and assessment.

Margin of Safety

TMDLs should reflect a MOS based on the uncertainty or variability in the data, the point and nonpoint source load estimates, and the modeling analysis. The MOS is a combination of implicit and explicit allowances. The implicit MOS is based on the selection of conservative values in the TMDL calculations. For example, the use of high-flow parameters in the calculation provides a conservative estimate of the TMDL because loads are usually highest during high flows.

Explicit allowances are percentages based on estimated measurement errors that are factored in when calculating the load allocations. For example, flow estimates for the development of the TMDL were based on the Red River Watershed flow model. To be conservative, a 5% MOS will be added to account for inaccuracies inherent in flow modeling estimates.

Margin of Safety for Metals (Aluminum)

For the permitted point sources, an implicit margin of safety is included in the discharge limits of the permit, therefore no MOS is added. For the nonpoint sources, however, the margin of safety is estimated to be an additional 20% for the TMDLs for metals in the Red River, excluding the background loads. This margin of safety reflects a 15% increase over the error factor described above because of the level of uncertainty that exists in the analytical techniques used for measuring metals concentrations in stream water, which have an accuracy range of 15%. Accordingly, a conservative margin of safety for metals increases the TMDL by 15%.

Table 16: Pollutant Source Summary

Pollutant Sources	Magnitude	Location	Potential Sources (% from each)
Point:	WLA:		
•Metals (chronic / acute aluminum)	0	Upper Red River	0
	2.63 (lb/day)	Middle Red River	0.4% - Red River WWTP
	0.34 (lb/day)	Lower Red River	0.4% - Molycorp #2, Spring 13, Spring 39
	0	Bitter Creek	0
	0	Placer Creek	0
	0	Cabresto Creek	0
•Stream Bottom Deposits (% fines)	0	Bitter Creek	0
•Turbidity (as TSS in lbs/day)	0	Pioneer Creek	0
Nonpoint:	LA + MOS:		
•Metals (chronic / acute aluminum)	23.2 (lb/day)	Upper Red River	100% - Natural, Resource extraction, Road maintenance/runoff
	586.07 (lb/day)	Middle Red River	99.6% - Rangeland, Resource extraction, Road maintenance/runoff
	81.46 (lb/day)	Lower Red River	99.6% - Rangeland, Resource extraction, Road maintenance/runoff
	50.0 (lb/day)	Bitter Creek	100% - Resource extraction, Road maintenance/runoff, Recreation, Natural
	10.0 (lb/day)	Placer Creek	100% - Natural, Resource extraction
	15.8 (lb/day)	Cabresto Creek	100% - Natural, Road maintenance/runoff
•Stream Bottom Deposits (% fines)	30.0 (% fines)	Bitter Creek	100% - Rangeland, Resource extraction, Road maintenance/runoff, Recreation, Removal of Riparian Vegetation, Streambank, Modification/Destabilization
•Turbidity (as TSS in lbs/day)	660.5 (lb/day)	Pioneer Creek	100% - Resource extraction, Recreation, Removal of Riparian Vegetation, and Streambank Modification/Destabilization

Margin of Safety for Stream Bottom Deposits

For nonpoint sources related to stream bottom deposits, the margin of safety is estimated to be an addition of 25% for the TMDL, excluding the background. This margin of safety incorporates a level of uncertainty that exists in the measurement of stream bottom deposits. There is also a potential to have error in measurements of nonpoint source loads due to equipment accuracy, time of sampling, etc. Accordingly, a conservative margin of safety for SBD increases the TMDL by 25%.

Margin of Safety for Turbidity

For nonpoint sources related to turbidity, the margin of safety is estimated to be an addition of 15% for the TMDL, excluding the background. This margin of safety reflects a 10% increase over the error factor for flow modeling described above because of the level of uncertainty that exists in the analytical techniques used for measuring turbidity in stream water, which have an accuracy range of 10%. Accordingly, a conservative margin of safety for turbidity increases the TMDL by 10%.

Consideration of Seasonal Variation

Data used in the calculation of this TMDL were collected during spring, summer, and fall to ensure coverage of any potential seasonal variation in the system. Critical condition is set to the highest flows for metals and turbidity. Data where exceedances were seen (usually during high monsoonal or snowmelt flows) were used in the calculation of the measured loads.

Future Growth

The Red River Watershed has its headwaters in the Wheeler Peak Wilderness area, and flows for approximately 27 miles through interspersed private and forest service managed land (Figure 4).

The Town of Red River is the largest community along the segments of the Red River that exhibit impaired water quality. Tourism is an important industry to the Town of Red River, and seasonal population fluxes will have an effect on future development. U.S. Census Bureau data indicate that the population of Red River grew by approximately 25% from 1990 to 2000 (NMEDD, 2001). By comparison, the population of Taos County increased by approximately 29% in the same period of time. Although these growth rates are somewhat higher than the overall rate of growth for New Mexico for the same period of time (which was approximately 20%), the total population growth is quite small. Census information for Red River showed a year-round population of 387 in 1990 and 484 in 2000. Continued growth at the same rate would result in only a small incremental change in population. Given the small contribution of aluminum discharge from the Red River WWTP, continued increases in population are not likely to contribute significantly to the overall aluminum loading in the Red River.

Sediment yield is probably a more significant factor to impairment of water quality when considering population growth. Increases in sediment yield are somewhat dependent on how the population growth and development occur. Compact development on level ground is likely to be yield less sediment than dispersed growth on sloping ground. Growth in the seasonal recreational facilities associated with the Town of Red River could also pose a risk for impairment of water quality by increased sediment yield.

No growth is expected in the watershed area that would contribute to significant increases in aluminum or sediment loads or increased turbidity that cannot be controlled with best management practice implementation.

MONITORING AND IMPLEMENTATION PLAN

Implementation of the TMDLs outlined above will require monitoring to determine improvements in the status of the Red River Watershed with respect to the support of designated uses. A monitoring plan to meet this requirement is outlined below. Data collected through monitoring activities will guide the planning and implementation of pollution control measures.

A series of natural physical conditions act upon the watershed, including high relief, climate, the presence of the sulfide-bearing altered volcanic rocks, and the high energy and high sediment load of the stream. In addition, human activities such as mining, road building and maintenance, home and town development, recreation and camping, and stream and drainage modifications are recognized sources of impact.

Impairment is derived primarily from NPS pollution, from both the Red River's main channel and from the entire watershed. In particular, impacts to the Bitter Creek tributary are being passed on to the Red River and the Rio Grande. These include erosion of soil resources, road and recreational impacts, pulse loading of sediments with total or dissolved constituents due to spring thaw or summer monsoon runoff, high turbidity and temperature, lack of riparian vegetation causing streambank destabilization and channel migration, and a combination of pH fluctuation and precipitate formation in the substrate.

The sources of local NPS impacts are the areas targeted for BMPs. The most obvious sources of some of these impacts, including turbidity, siltation, heavy metal loading, riparian habitat destruction, and destabilization of streambanks, relate to natural and anthropogenically accelerated erosion of sulfide-bearing altered volcanic rocks in the region. The goal should be to prevent erosion and sedimentation impacts from reaching the river channel and to reduce turbidity impacts by providing a means to capture and stabilize soils and suspended sediment and to inhibit their concentration in runoff during the intermittent periods of channel flow.

Monitoring Plan

Pursuant to Section 106(e)(1) of the Federal Clean Water Act, the SWQB has established appropriate monitoring methods, systems and procedures in order to compile and analyze data on the quality of the surface waters of New Mexico. In accordance with the New Mexico Water Quality Act, the SWQB has developed and implemented a comprehensive water quality monitoring strategy for the surface waters of the State. The monitoring strategy establishes the methods of identifying and prioritizing water quality data needs, specifies procedures for acquiring and managing water quality data, and describes how these data are used to progress toward three basic monitoring objectives: to develop water quality-based controls, to evaluate the effectiveness of such controls, and to conduct water quality assessments.

The SWQB utilizes a rotating basin system approach to water quality monitoring. In this system, a select number of watersheds are intensively monitored each year with an established return frequency of every five to seven years.

The SWQB maintains current quality assurance and quality control plans to cover all monitoring activities. The planning document, "Quality Assurance Project Plan for Water Quality Management Programs" (QAPP), is updated annually (NMED, 1998-2001). Current priorities for monitoring in the SWQB are driven by the 303(d) list of streams requiring TMDLs. Short-term efforts will be directed toward those waters which are on the EPA TMDL consent decree (Forest Guardians and Southwest Environmental Center v. Carol Browner, Administrator, US EPA, Civil Action 96-0826 LH/LFG, 1997) list and which are due within the first two years of the monitoring schedule. Once assessment monitoring is completed, those reaches showing impacts and requiring a TMDL will be targeted for more intensive monitoring.

The methods of data acquisition include fixed-station monitoring, intensive surveys of priority water bodies, including biological assessments, and compliance monitoring of industrial, federal, and municipal dischargers, and are specified in the SWQB Assessment Protocol (SWQB/NMED revised 10-2-00).

Long-term monitoring for assessments will be accomplished through the establishment of sampling sites that are representative of the waterbody and which can be revisited every five to seven years. This gives an unbiased assessment of the waterbody and establishes a long term monitoring record for simple trend analyses. This information will provide time relevant information for use in 305(b) assessments and to support the need for developing TMDLs. The approach provides:

- A systematic, detailed review of water quality data, allowing for a more efficient use of valuable monitoring resources.

- Information at a scale where implementation of corrective activities is feasible.

- An established order of rotation and predictable sampling in each basin which allows for enhanced coordinated efforts with other programs.

- Program efficiency and improvements in the basis for management decisions.

It should be noted that a basin would not be ignored during its sampling hiatus. The rotating basin program will be supplemented with other data collection efforts. Data will be analyzed, field studies will be conducted to further characterize acknowledged problems, and TMDLs will be developed and implemented. Both long-term and field studies can contribute to the 305(b) report and 303(d) listing processes.

The following schedule is a draft for the sampling seasons through 2004 and will be followed in a consistent manner to support the New Mexico Unified Watershed Assessment (UWA) and the Nonpoint Source Management Program. This sampling regime allows characterization of seasonal variation and through sampling in spring, summer, and fall for each of the watersheds.

- 1998 Jemez Watershed, Upper Chama Watershed (above El Vado), Cimarron Watershed, Santa Fe River, San Francisco Watershed

- 1999 Lower Chama Watershed, Red River Watershed, Middle Rio Grande, Gila River Watershed (summer and fall), Santa Fe River

- 2000 Gila River Watershed (spring), Dry Cimarron Watershed, Upper Rio Grande 1 (Pilar north to the NM/CO border), Shumway Arroyo

- 2001 Upper Rio Grande 2 (Pilar south to Cochiti Reservoir), Upper Pecos Watershed (Ft Sumner north to the headwaters)

- 2002 Canadian River Watershed, San Juan River Watershed, Mimbres Watershed

- 2003 Lower Pecos Watershed (Ft. Sumner south to the NM/TX border including Ruidoso), Lower Rio Grande (southern border of Isleta Pueblo south to the NM/TX border)

- 2004 Rio Puerco Watershed, Closed Basins, Zuni Watershed

Use of Biological Data to Assess Aquatic Life Uses in the Red River

The EPA (1990) defines biological criteria, or biocriteria, as "numerical values or narrative expressions that describe the reference biological integrity or aquatic communities inhabiting waters of a given designated aquatic life use." According to the EPA:

> biological criteria are valuable because they directly measure the conditions of the resource at risk, detect problems that other methods may miss or underestimate, and provide a systematic process for measuring progress resulting from the implementation of water quality programs. Biological criteria require direct measurements of the structure and function of resident aquatic communities to determine biological integrity and ecological function. They supplement, rather than replace chemical and toxicological methods. It is EPA's policy that biological survey methods be fully integrated with toxicity and chemical-specific methods and that chemical-specific criteria be used as independent evaluations of non-attainment of designated uses. (EPA, 1990).

Standard Protocols for Use Attainment

The NMED has established standard protocols for assessing the attainment of designated uses in surface waters of the State (NMED, 2000a). These protocols recognize that assessments of beneficial use attainment "should consider and integrate, whenever possible and appropriate, the results of various monitoring data types." Data types include biological, habitat/stream channel condition, chemical/physical, and toxicological monitoring data. For aquatic life use assessments, it is possible that data of differing types may lead to differing use attainment determinations for the same reach. For example, while available physical/chemical data indicate a partial support designation, the available biological data may indicate a full support designation.

Generally, when there are two conflicting determinations, the determination based on the data of highest quality will be chosen. If more than two data types are available for assessment, a preponderance of evidence approach will be adopted, as specified by NMED (2000a).

The NMED protocols provide general guidelines for implementing assessments and interpreting field data for biocriteria. The fish and benthic macroinvertebrate data collected since 1997 provide a site-specific foundation for defining and implementing a biological assessment for the main stem of the Red River and its tributaries.

In considering the development of biological assessment for this system, it is important to recognize that heavy stocking of the river with rainbow trout in the vicinity of the Town of Red River artificially increases the total population of trout in this river. While not specifically investigated in the studies of this river to date, this stocking increases competition among fish in the river, especially for cover habitat and food supply. It also increases fishing pressure on all trout species, resulting in depressed numbers of naturally reproducing trout in the Red River. The stocked rainbow trout likely also cause some increase in predation pressure and decrease in the size of the river's benthic macroinvertebrate population. In developing a biological assessment for this river, these interactions should be recognized. Unless specific studies and data are developed to quantify these effects, however, their influences can only be incorporated through the use of best professional judgment, as specified by NMED (2000a).

Due to the population patterns observed in this system, biological assessment should focus on (1) trout biomass (excluding rainbow trout biomass), (2) density of benthic invertebrate taxa (e.g., total number per unit area), and (3) total number of benthic taxa (e.g., taxa per unit area). Fish should be collected using electrofishing techniques consistent with those used in previous studies of the river and/or the standardized protocols specified by NMED (2000a). In addition, the benthic samples should be collected in riffle habitats at sites with similar characteristics using techniques consistent with those used in previous studies and/or the standardized protocols specified by NMED (2000a).

Biological Assessment Methodology

Reference conditions for biomonitoring of the Red River through the vicinity of the Questa Ranger Station would be defined by the average for sample data collected from two sites: (1) upstream of Zwergle Dam, and (2) upstream of Hansen creek. Results for these two sites regularly include the maximum trout biomass (excluding rainbow trout) and benthic macroinvertebrate densities and number of taxa (Appendix D). Sites specifically sampled to assess attainment of beneficial uses would include locations near Junebug Campground, downstream of Hansen Creek, and Questa Ranger Station; this last site would be targeted as the key site to judge potential attainment for CWF in the Red River system. A minimum of three fish and three benthic macroinvertebrate samples would be collected from each sample site during each assessment cycle to provide adequate reference and assessment information.

Attainment of beneficial uses for CWF in perennial tributaries of the Red River would be assessed using reference information that includes the averaged data from sampling sites on the Middle Fork of the Red River and on Columbine Creek (Figure 7). The same three assessment parameters and minimum sampling requirements used for the main stream of the Red River would apply to the tributaries. Tributaries would be assessed at selected sampling sites.

Interpretation of the data from these assessments would follow the guidance provided in Table 1 of the NMED (2000a) assessment protocol, as follows:

- Sites with conditions greater than 83% of the reference would be considered to fully support the designated uses
- Sites with conditions at 54% to 79% of the reference would be considered to be slightly impaired
- Sites with conditions at 21% to 50% of the reference would be considered moderately impaired
- Sites with conditions less than 17% of the reference would be considered severely impaired.

If conditions for two of the three assessment parameters were found to meet the definitions for a higher category of attainment in the assessment, the site would be characterized at the higher level of use attainment.

Implementation Plan

Management Measures

To implement the TMDLs, economically achievable management measures are implemented to control the addition of pollutants from existing and new categories and classes of nonpoint sources of pollution. These measures reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives (EPA, 1993). These BMPs should focus on the sites with the highest load reduction potential (e.g., Hansen Creek, Goathill Gulch, and Capulin Canyon areas) and the greatest opportunity to protect established uses (e.g., HQCWF in upper Red River) and rehabilitate degraded reaches (e.g., Middle Red River). Stakeholder and public outreach and involvement in the implementation of the TMDLs will be ongoing. Stakeholder participation will include both choosing and implementing BMPs, as well as volunteer monitoring activities.

Introduction (Sources of Pollutants)

The uptake and transport of metals in surface waters can pose a considerable nonpoint source pollution problem. Metals such as aluminum, lead, copper, iron, zinc and others can occur naturally in watersheds in amounts ranging from trace to highly mineralized deposits. Some metals are essential to life at low concentrations but are toxic at higher concentrations. Metals such as cadmium, lead, mercury, nickel, and beryllium represent known hazards to human health. The metals are continually released into the aquatic environment through natural processes, including weathering of rocks, landscape erosion, geothermal or volcanic activity. The metals may be introduced into a waterway via headcuts, gullies or roads. Depending on the characteristics of the metal, it can be dissolved in water, deposited in the sediments or both. Metals become dissolved metals in water as a function of the pH of a water system. In urban settings, storm water runoff from paved and developed area can increase the mobilization of many metals into streams.

Examples of sources that can cause metals contamination:

- Activities such as resource extraction, recreation, some agricultural activities and erosion can contribute to nonpoint source pollution of surface water by metals.

- Storm water runoff in industrial areas may have elevated metals in both sediments and the water column.

Sources of Turbidity and Stream Bottom Deposits

Turbidity is a measurement of the reduction of the penetration of light through natural waters and is caused by the presence of suspended particles. Turbidity is a qualitative measure of water clarity or opacity and is reported in NTU.

The turbidity standard addresses excessive sedimentation, which can lead to the formation of stream bottom deposits that can impact the aquatic ecosystem. Suspended solids such as clay, silt, ash, plankton, and organic materials generally cause turbidity. Some level of turbidity is a function of a stream's natural process of moving water and sediment.

Examples of sources that can cause excessive turbidity and SBD fines include:

- Runoff from exposed soil (such as construction sites)

- Improperly maintained roads

- Eroded streambanks

- Activities that occur within a stream channel (such as some forms of mining)

- Removal of riparian vegetation
- Naturally occurring situations such as runoff events

Fire Effects on Forest Soils and Erosion

Increased sediment loads and turbidity can also result from forest fires. The effects of a forest fire on the forest floor can range from the removal of forest floor litter to the total consumption of the forest cover and floor and the alteration of the mineral soil. With the loss of vegetation and the alteration of the mineral soil, erosion can become a large problem. The degree to which a forest fire affects the soil is dependent on two factors (1) the amount of vegetation and litter that is consumed, and (2) the degree and extent of soil heating.

Vegetation plays an important role in protecting and enhancing forest soils. Vegetative cover protects the underlying soil from the impact force of raindrops. Litter from the vegetative cover also offers soil protection and supplies organic matter that may be worked into the uppermost soil horizon where it facilitates infiltration and water storage. If a forest fire destroys the litter layer on the forest floor, raindrop impact (Farmer and Van Haveren, 1971), overland flow (Meeuwig, 1971), gravity, wind, and animal activity can initiate the erosion process. If a forest fire is severe enough, hydrophobic organic substances in the litter may be volatilized, allowing them to move downward in the soil profile where they can condense and become and water repellent layer (DeBano, 1981; DeBano et al., 1998). Water repellent soils can have lower infiltration rates and can lead to increased erosion (Robichaud, 1996).

The degree of erosion after a forest fire also depends upon other factors such as fire frequency, climate, vegetation, topography, geology, and soils (Swanson, 1981). Erosion and runoff are often the result of lower infiltration rates and decreased water absorption, particularly in regions receiving high intensity summer storms (Wells et. al., 1979).

In May of 1996, the Hondo Fire consumed approximately 7,500 acres in the Lama Canyon area (southeast of the fish hatchery) of the Red River watershed. The fire effects discussed above are visible today, as well as fire recovery responses such as establishment of vegetation, plant succession, and reestablishment of channel stability.

Actions to be Taken (Recommended Best Management Practices)

For the Red River Watershed the focus will be on sediment control and mitigation of acidic seepage. BMPs for sediment in this area will include proper road maintenance practices and drainage controls, riparian plantings, and hydrogeomorphic river restoration. BMPs for acidic seepage will need to address aluminum exceedance through the use of wetlands, anoxic alkaline drains, interception systems, mine dewatering systems (Vail, 2000), and treatment of acid rock drainage. The USFS is presently involved in a variety of management activities and improvement projects addressing sources of NPS pollution originating on properties it manages in this watershed. A list of current and proposed USFS projects is contained in Table 17. The SWQB will work with the USFS, the New Mexico State Highway and Transportation Department (NMSHTD), the Town of Red River, the Red River Watershed Group, and private landowners to implement BMPs throughout the watershed.

Table 17: Questa Ranger District Plan List of Current and Proposed Projects by Waterbody

Waterbody	Project
Upper Red River	Upper Red River Abandoned Mines Preliminary Assessment/Site Investigation Goose Creek Road Improvement Project (TEA-21 w/ Town of RR) Middle Fork Road Improvement Project (10% Project)* Upper Red River Wildland Urban Interface - fuel reduction project Goose Creek Trial Improvements (10% Project)
Middle Red River	Mallette Road Surfacing Project (10% Project) Mallette Park Hazardous Waste Removal Sawmill Road Improvement Project (TEA-21 w/ Town of RR) Middle Red River Wildland Urban Interface - fuel reduction project USGS/NMED Groundwater Study - authorization of data collection and liaison work
Lower Red River	Questa/Lama Wildland Urban Interface - fuel reduction project
Bitter Creek	Bitter Creek Abandoned Mines Preliminary Assessment/Site Investigation Riparian Planting at Logjam*
Pioneer Creek	Pioneer Creek Abandoned Mines Preliminary Assessment/Site Investigation Pioneer Canyon Wildland Urban Interface - fuel reduction project Red River Ski Area Revegetation Plan (update)
Placer Creek	Placer Creek Abandoned Mines Preliminary Assessment/Site Investigation
Cabresto Creek	Cabresto Meadows Recreation Improvements Bull Creek and Lake Fork Trail Improvements (10% project)

* Indicates proposed projects in the conceptual stages.

During TMDL implementation, known point sources will be addressed through the permit process implemented by the EPA and NMED for surface and groundwater discharges, respectively. NPS contributions of aluminum, turbidity, and sedimentation will be addressed through best management practices implementation.

Best Management Practices to Control Metal Contamination

BMPs can be implemented to address and remediate metal contamination. They include, but are not limited to:

- Wetlands are used to filter runoff water and sediment from source areas in the watershed. Metals may be taken up in the root systems of wetlands vegetation and sequestered in anoxic sediments, which prevents them from entering a waterway (*The Use of Wetlands for Improving Water Quality to Meet Established Standards*, 1992, Filas and Wildeman.).

- Maintaining circumneutral pH in a stream. Neutral to slightly alkaline pH waters will generally not pose a metal exceedance problem. An acidic or highly alkaline pH will dissolve available metals.

  In such a case, a remedy for metals contamination could be an adjustment of the pH of runoff before it enters the water body. An approach may be the construction of an anoxic alkaline drain to raise the pH and precipitate the contained metals. An anoxic alkaline drain is constructed by placing a high pH material in a trench between runoff and the stream to be used as a buffer (*Red River Groundwater Investigation—NMED-SWQB-Nonpoint Source Pollution Section*, 1996, D. Slifer).

- A method for reducing metals used in controlled situations includes the use of sulfate and sulfate reducing bacteria. The sulfate (if not already present) and the sulfate reducing bacteria are applied into a stagnant water column or saturated sediments. This provides a mechanism for some metals to precipitate out of solution (*A Treatment of Acid Mine Water Using Sulfate-Reducing Bacteria*, 1979, Wakao, Saurai, and Shiota).

- Storm water and construction BMPs can be used to divert flows from metal-producing areas and direct them away from streams into areas where the flows may infiltrate, evaporate, or accumulate in sediment retention basins.

  (*Conservation Design for Stormwater Management: A Design Approach to Reduce Stormwater Impacts from Land Development and Achieve Multiple Objectives Related to Land Use*, 1997, Delaware Department of Natural Resources and Environmental Control, Sediment and Stormwater Program & the Environment Management Center, Brandywine Conservancy.)

Best Management Practices to Control Turbidity and Stream Bottom Deposits

There are a number of BMPs that can be utilized to address turbidity and SBDs, depending on the source of the sediment. Such BMPs include:

- Protection and/or development of healthy riparian streambank vegetation serves as a filter for soils that are transported during surface runoff. This runoff could be the result of activities that disturbed soils or caused a loss of vegetative ground cover.

  Riparian vegetation also helps to stabilize riverbanks with root structures, which prevents excessive bank erosion and helps maintain the stability and natural morphology of the stream system (*Stream Corridor Restoration – Principles, Processes, and Practices*, 1998, The Federal Interagency Stream Restoration Working Group).

- Placement of silt fences between roads and watercourses to prevent soils disturbed during road and other construction activities from being carried into watercourses. Silt fences act like a filter to trap sediment that is carried during runoff events. When maintained properly, silt fences are an effective erosion control measure that can be used throughout New Mexico (*Erosion and Sediment Control Manual*, 1993, Environment Department, Surface Water Quality Bureau).

- Placement of straw mulch on soils that have lost vegetative groundcover during severe forest fires. The straw mulch helps prevent erosion during rainstorms and snowmelt by holding the bare topsoil and ash in place. The mulch can also aid in the infiltration of water and replace ground litter. This method works well on gentle slopes where there is no wind (*Cerro Grande Fire Burned Area Emergency Rehabilitation [BAER] Plan*, 2000, Interagency Baer Team).

Best Management Practices (BMPs) to Lessen Forest Fire Risk and Severity

Many forest practices exist that can help lessen the risk of forest fire and the severity of a fire. These include thinning, pruning, removal of litter and brush by prescribed burning or manual removal, and construction of fire breaks. However, many of these options are not available on the Red River Watershed. First, much of the Red River Watershed forestlands is inaccessible due to steep terrain and canyons. The construction of new roads is not an option due to sensitive soils, steep terrain, and the short reach that many roads would have. Other parts of the watershed fall within areas designated as wilderness or wilderness study areas, and are therefore exempt from many management activities. Therefore, if a large, severe fire were to occur in the watershed area, the USFS would concentrate fire suppression at the urban/wildland interface where the edges of communities such as Red River, Upper Red River, and Questa meet the forests (Thibedeau, 2001).

Additional sources of information for BMPs to address metals, turbidity, and stream bottom deposits are listed below. Some of these documents are available for viewing at the New Mexico Environment Department, Surface Water Quality Bureau, Watershed Protection Section Library, 1190 St. Francis Drive, Santa Fe, New Mexico.

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Forestry

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- Unknown; Environmental Management. Best Management Practices.
  Construction Sites
  Developed Areas
  Sand and Gravel Pits
  Farms, Golf Courses, and Lawns

Other BMP Activities in the Watershed

Sediment retention pond, Bitter Creek area

The following activities have occurred, are occurring, or are in the planning stages to address metal, sediment, and turbidity sources or other nonpoint source issues in the Red River watershed.

Molycorp activities include developing closeout plans for both mining and tailings sites in response to New Mexico's Mining Act requirements. These activities include multiple characterization and scoping reports, ongoing water quality monitoring, and characterization of background loads throughout the watershed. Groundwater and surface water discharges are subject to requirements imposed by the NMED Ground Water Quality Bureau (GWQB) and by EPA through the permitting process. Effective February 1, 2001, the Molycorp Mine was issued a renewal of its NPDES permit. The permit prohibits the mine from discharging any pollutant attributable to a point source from mining operations except in trace amounts. Under the conditions of the renewal permit, the mine is required to install, within two years of the effective date of their renewal permit, a groundwater extraction well and two seepage interception systems. The extraction well will be placed southwest of the old mill site. The seepage interception systems will be French drains placed upstream of flow station 13 on the north side of the Red River (Figure 6), east of Goathill Campground and Capulin Canyon (EPA, 2000).

The negative but temporal impacts of storm water runoff have also been addressed by the mine. Management of storm water runoff by Molycorp has apparently been effective in eliminating surface discharges from the mine site to Red River (based on NPDES reporting and on field observations during storm events).

The USFS has been investigating mine wastes sites on federal lands near the town of Red River (Bitter, Pioneer, and Placer Creek drainages). These studies have examined ways to mitigate off-road vehicle use in Cabresto and Mallette Canyons. In addition, the USFS has been completing National Environmental Policy Act (NEPA) analysis for two

Molycorp investigations, including a proposed structure to capture and treat acid seeps in the Capulin Canyon area (NMED, 2000b).

Nonpoint source pollution activities in the Bitter Creek subwatershed may serve as a test of BMPs for controlling sediment loads. A range of appropriate BMPs have been evaluated by a consortium of interagency experts. These include reestablishment of stable drainage through the existing slump; regrading, structural and vegetative stabilization of slump material; and rebuilding and crowning the Bitter Creek Road with bar ditches. In addition, construction of an engineered structure above the Bitter Creek Road was used to direct runoff across Bitter Creek Road to a discharge point with adequate energy dissipation above Bitter Creek. The lower incised and braided channel will be graded into a meandering channel, and vegetative and rock deflectors, bank armoring, and revegetation of the riparian/wetland systems will also be constructed (NMED, 2000b).

Based on the Bitter Creek study, appropriate BMPs to manage sedimentation throughout the Red River Watershed include:

- Road maintenance improvements, including elevating and crowning the surface of the road, installing bar ditches, and reducing runoff time on the road
- Installation of off-channel sediment catchment basins along Bitter Creek
- Slope stability measures, including introducing vegetation
- Channel definition, bank stabilization, and riparian enhancement
- Installation of gully plugs/check dams on head cuts
- Management of gravel accumulation
- Establishment of confined channel with added sinuosity and a riparian setting
- Installation of sediment basin at the toe of waste pile or erosional scar area slopes

The effectiveness of implemented BMPs will be verified by sampling for appropriate parameters upstream and downstream of BMP locations and by comparing photographic documentation of before and after conditions. Sampling could be done in conjunction with the watershed monitoring plan.

Coordination

Public awareness and involvement will be crucial to the successful implementation of this plan and improved water quality in the Red River Watershed. The WRAS (Watershed Restoration Action Strategy) is a written plan intended to provide a long-range vision for various activities and management of resources in a watershed. It includes opportunities for private landowners and public agencies to reduce and prevent impacts to water quality. This long-range strategy will be instrumental in coordinating and achieving reduced metal, sediment, and turbidity loads, and in improving overall water quality in the watershed. SWQB staff will provide any needed technical assistance, such as the selection and application of BMPs needed to meet the WRAS goals.

Stakeholder and public outreach and involvement in the implementation of pollution control measures to achieve the TMDLs will be an ongoing process. Potential stakeholder participation will include choosing and installing BMPs, volunteer activities, and monitoring. The SWQB will work with stakeholders in this watershed to encourage the implementation of BMPs. Coordination efforts should focus on:

- Providing support for outreach activities
- Compiling relevant water quality data
- Working with stakeholder groups to identify areas/sites of significant contributions; to determine the practicality and suitability for cleanup of those areas/sites, and to prioritize areas for possible inclusion in a watershed cleanup plan (implementation plan)
- Identifying and helping the stakeholders initiate an early pilot area cleanup using readily available resources
- Developing a scope for a watershed restoration action plan in concert with the plan of implementation being developed by the TMDL contractor

Stakeholders in this process will include the SWQB, NMSHTD, local government, private landowners, environmental groups, and the general public.

For example, the Red River-Questa Watershed Association has been involved with SWQB project activities, and is actively engaged in the public participation process through educational and meeting activities. An NPS outreach coordinator will be able to publicize the various BMP approaches that have been taken and distribute information on the project in the NPS newsletter *Clearing the Waters* by publishing an account distilled from this project summary report. A watershed-specific newsletter could also be developed to serve as a clearinghouse of activities underway within the watershed and to help clarify complex issues. Local meetings at specific locations in the watershed will help identify individual views and promote dialogue and communications on specific issues and needs.

Other groups to coordinate with include New Mexico Office of the Natural Resources Trustee, USFS, New Mexico Department of Game and Fish, Molycorp, Inc., Amigos Bravos, and other groups whose activities are related to the location and nature of pollutant sources.

Implementation of BMPs within the watershed to reduce pollutant loading from nonpoint sources will be accomplished on a voluntary basis. Reductions from point sources will be addressed in revisions to discharge permits.

A time line for implementing the WRAS is provided below.

Time Line for Implementation of Pollution Control Measures

Implementation Actions	Year 1	Year 2	Year 3	Year 4	Year 5
Public outreach and involvement	X	X	X	X	X
Establish milestones	X				
Secure funding	X		X		
Implement management measures (BMPs)		X	X	X	
Monitor BMPs			X	X	X
Determine BMP effectiveness				X	X
Reevaluate milestones					X

Section 319(h) Funding Options

The Watershed Protection Section of the SWQB provides EPA 319(h) funding to assist in implementation of BMPs to address water quality problems on reaches that are on the 303(d) list or are located within Category I Watersheds, as identified under the UWA of the CWAP.

New Mexico's Clean Water Action Plan has been developed in a coordinated manner with the State's 303(d) process. All Category I watersheds identified in New Mexico's Unified Watershed Assessment process are totally coincident with the impaired waters lists for 1996 and 1998 as approved by EPA. The state has given a high priority for funding, assessment, and restoration activities to these watersheds.

These monies are available to all private, for profit, and nonprofit organizations that are authenticated legal entities, or governmental jurisdictions including cities, counties, tribal entities, and federal and state agencies.

Proposals are submitted by applicants through a Request for Proposals (RFP) process and require a non-federal match of 40% of the total project cost consisting of funds and/or in-kind services. Further information on funding from the CWA, Section 319(h) is available on the New Mexico Environment Department website (http://www.nmenv.state.nm.us).

Assurances

New Mexico's Water Quality Act (Act) authorizes the Water Quality Control Commission to "promulgate and publish regulations to prevent or abate water pollution in the state" and to require permits. The Act authorizes a constituent agency to take enforcement action against any person who violates a water quality standard. Several statutory provisions on nuisance law could also be applied to nonpoint source water pollution. The Water Quality Act (NMSA 1978, Ch. 74) also states in §74-6-12(a):

> ***The Water Quality Act (this article) does not grant to the commission or to any other entity the power to take away or modify the property rights in water, nor is it the intention of the Water Quality Act to take away or modify such rights.***

In addition, the State of New Mexico Surface Water Quality Standards (Sec. 20.6.4.6C and Section 20.6.4.10C) states:

> ***These water quality standards do not grant the Commission or any other entity the power to create, take away or modify property rights in water.***

New Mexico policies are in accordance with the federal Clean Water Act §101(g):

> ***It is the policy of Congress that the authority of each State to allocate quantities of water within its jurisdiction shall not be superseded, abrogated or otherwise impaired by this Act. It is the further policy of Congress that nothing in this Act shall be construed to supersede or abrogate rights to quantities of water which have been established by any State. Federal agencies shall co-operate with State and local agencies to develop comprehensive solutions to prevent, reduce and eliminate pollution in concert with programs for managing water resources.***

The description of legal authorities for regulatory controls/management measures in New Mexico's Water Quality Act does not contain enforceable prohibitions directly applicable to nonpoint sources of pollution. Therefore, the NMED's nonpoint source water quality management approach is based on voluntary actions. The state provides technical support and grant monies for implementation of BMPs and other NPS prevention mechanisms through §319 of the Clean Water Act. The Nonpoint Source Program administers the §319 grants and coordinates with the Nonpoint Source Taskforce. The Nonpoint Source Taskforce is the New Mexico statewide focus group representing federal and state agencies, local governments, tribes and pueblos, soil and water conservation districts, environmental organizations, industry, and the public. This group meets on a quarterly basis to provide input on the §319 program process, to disseminate information to other stakeholders and the public regarding nonpoint source issues, to identify complementary programs and sources of funding, and to help review and rank §319 proposals.

To obtain reasonable assurances for implementation in watersheds with multiple landowners, including federal, state and private land, NMED has established MOUs with various federal agencies, in particular the USFS and the BLM. MOUs have also been developed with other state agencies such as the NMSHTD. These MOUs provide for coordination and consistency in dealing with nonpoint source issues.

Milestones

Milestones will be established to determine if control actions are being implemented and if the target TMDLs are being attained. Site specific milestones will be based on the BMPs implemented at each site. Examples include achieving a percentage reduction in stream bottom deposits and aluminum precipitate within a certain time frame, updating or developing MOUs with other state and federal agencies by a certain date to ensure protection and restoration in this watershed, and increasing education and outreach activities regarding sediment erosion in this watershed.

Milestones will be reevaluated periodically, and further implementation of pollution control strategies in support of these TMDLs will be revised based on this reevaluation. The process will involve monitoring pollutant loading, tracking implementation and effectiveness of controls, assessing water quality trends in the water body, and reevaluating the TMDLs for attainment of water quality standards.

Given the relatively high background loading discussed in Section 5, implementation of BMPs in the Red River Watershed may not achieve compliance with water quality standards for a CWF. Another option for the Red River may be to conduct a use attainability analysis (NMWQCC, 2001). This analysis would determine whether Red River is actually capable of supporting its designated use as a CWF.

Public Participation

Public participation is solicited in the development of these TMDLs. Appendix I includes a flow chart of the public participation process. The draft TMDL was made available for a 30-day comment period starting in April 2002. A response-to-comments form is included as Appendix J of this document. The draft document notice of availability was extensively advertised via newsletters, e-mail distribution lists, web page postings (http://www.nmenv.state.nm.us/), and press releases to area newspapers.

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List of Appendices

Appendices

Appendix A: Red River TMDL Bibliography

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Appendix B: Flow Modeling Methodology

The mass loading during a specified time interval (e.g., day) of any constituent is related to flow through the following equation:

Equation B1. Mass Load (mass units) = Q x C

Where Q = Discharge (volumetric units) and C = Concentration (mass per unit volume). Therefore, the discharge for each designated segment (natural or artificial) must be estimated in order to determine the TMDL.

Background

The following describes the approach applied to estimate ungauged inflows to the Red River between the USGS gage station/SWQB established flow measurement site below the Zwergle dam site near Red River, New Mexico, and the confluence of the Red River with the Rio Grande. Estimation of ungauged inflows is one of the most difficult, and common, tasks in hydrology. All approaches take into account contributing area. Some approaches add other variables such as precipitation, elevation of the gage site, and/or land use patterns. Many approaches use the "transfer" method whereby information from similar gauged sites is "transferred" to the site of interest. In sparsely gauged areas, this transfer can be problematic, as the gauged sites may be dissimilar in area, elevation, or land use and the information may not be reliably transferred.

Furthermore, groundwater flow in the watershed is controlled by fractures and faults, preferred channels within debris flow material, and differences in hydraulic conductivity between bedrock, mine waste rock piles (near Molycorp), and valley fill/alluvium. Hydrogeologic units include a Pre-Cambrian aquitard, volcanic and sedimentary rock aquifers, and valley fill alluvial or debris flow aquifers. Groundwater gradients are toward the Red River, except for the cone of depression created by mine dewatering. Fan delta deposits at the mouths of tributary canyons are the principal hydraulic connection between the river and upgradient sources.

The Red River watershed is sparsely gauged. Some information has been collected from contributing streams and from points of seepage. This information, although not definitive, does allow a "reality" check on estimated values.

Methods

The Red River flow model stations were positioned below major tributaries, NPDES outfalls, and known acidic seepage locations. All stations lie between the former Zwergle gage station, which is located just above the town of Red River, and the mouth on the Rio Grande. The flow stations also coincide with SWQB and biological stations when present. Automated measurement tools within ArcView were used to determine sub-basin areas for significant tributaries to the Red River and the watershed areas above each of the flow stations.

Model development involved matching, as closely as possible, measured streamflows at the current and former gage stations. Streamflow records for these stations were downloaded from the National Water Information System web site (USGS, 2001). Data from the last 50 years at the Questa gage station was used to estimate the missing flows for the same time period at the remaining gage stations. This was accomplished for the three months of interest by developing a relationship between the data collected at the Questa station with each of the remaining stations. The result was a target average daily streamflow value for May, August, and October (Table B1) that the flow model attempted to match at each of the USGS stations on the Red River.

Table B1. Target Streamflows for USGS Gage Locations

Location	Flow Model Station	Target Streamflow (cfs)		
		May	August	October
Near Red River Gage	N/A	35.0	16.0	7.15
Zwergle Gage	1	49.6	20.6	11.0
Questa Gage	14	118	38.8	22.0
Fish Hatchery Gage	17	164	64.7	48.8
Mouth Gage	18	169	79.8	60.7

The average daily streamflows at the remaining model stations were simulated based on the area-weighted gains between the Zwergle and Questa gage stations, and between the Questa and fish hatchery gage stations. These gains were apportioned among the tributaries and groundwater seepage areas as described below.

Area-Weighting Approach

The approach used in the Red River TMDL study relies on measured river flows and various point measurements of tributary and seepage flows to estimate the ungauged flows. The approach will be described using the river reach between the gage sites at Questa (Red River near Questa, NM) and Zwergle. The contributing area to the river flow at Zwergle is 25.7 square miles. At Questa, the area is 113 square miles. Therefore, the intervening contributing area is 87.3 square miles, 44.5 square miles of which is assigned to tributaries and the remaining 42.8 square miles is assigned to non-tributaries, or seeps in this usage. The river distance between the Zwergle and Questa is 14 miles allowing direct (not time-lagged) comparisons between the average daily flows at the two sites. The gains or losses in the average daily flows can be calculated as:

$$\textit{Equation B2.} \quad dQ = Q_Q - Q_Z$$

Where dQ is the difference in the average daily flow (for a specific measurement day such as May 5, 1970, for example) between Questa and Zwergle, Q_Q is the average daily flow at Questa and Q_Z is the average daily flow at Zwergle for the same day. The value of dQ can be either positive (gains) or negative (losses). The period of overlapping measurements for the two sites or stations is from May 1, 1963 through December 31, 1973, or 3,898 days. The gain or loss on a daily basis is calculated as:

$$\textit{Equation B3.}\quad q = dQ/dA$$

Where q is the contributing flow in cfs per square mile and dA is the change in area between the stations. Rearranging and expanding equation (B3) yields:

$$\textit{Equation B4.}\quad dQ = q_t A_t + q_s A_s$$

Where q_t and A_t are the contributing flow and area from the designated tributaries and q_s and A_s are the same measures for the non-tributaries, or seeps. The total change of area is:

$$\textit{Equation B5.}\quad dA = A_t + A_s$$

Equation (B4) can be modified to:

$$\textit{Equation B6.}\quad dQ = q_s (K A_t + A_s)$$

Where $K = q_t / q_s$. The problem is to assign values to q_t, q_s, and/or K. These values are dynamic, i.e. they change with time, and vary from source to source. However, without detailed and prolonged measurements, only general values can be used.

Estimating Values

Because there are more unknowns than equations, the K factor was introduced to relate q_t and q_s. The range in K, based on the small number of point samples, is between 1 and 3, with 1 appropriate for the low flow months of August and October and 3 appropriate for the high flow month of May (the three months chosen for detailed analyses). Once a value of K was selected, then an optimum value of q_s could be calculated that yielded a minimum least squared errors summation or:

$$\textit{Equation B7.}\quad Min \sum (dQ\ measured - dQ\ estimated)^2$$

Where dQ measured is from equation (B2) and dQ estimated is from equation (B6). It should be obvious that the best estimate is the one that will yield a dQ equal to the average of the dQ values found from equation (B2). This optimal value is static over the time period from which it is derived, such as the May flows. Because q_s is a really a dynamic value, a refinement was developed. A linear regression model was developed for q_s as:

$$\textit{Equation B8.}\quad q_s = a + b\, Q_Z$$

Where a and b are regression parameters. The value of q_s was related to the flow at Zwergle because that flow was the known upstream boundary condition. The individual values of q_s were back calculated by rearranging equation (B6) with an assumed K value and the difference in daily flows found from equation (B2). The relationships for the Zwergle to Questa reach for the months of May, August, and October were reasonable and were incorporated into the flow estimation model. The final form of the estimation equation for the Zwergle to Questa reach is:

$$Equation\ B9.\quad Q_Q = Q_Z + (a + b\ Q_Z)\ x\ (K\ A_t + A_s)$$

Equation (B9) was used to estimate the daily flows at Questa based on the flow at Zwergle and the estimated inflows. The results were reasonable. This comparison was made for all three detailed months and for the entire period of overlapping record.

Similarly, the reach between Questa and the Red River below Fish Hatchery near Questa, NM, site was also analyzed. It this reach, the K value was set to 0.0 (no tributary inflows, i.e. A_t was 0.0 as well) and only q_s was considered. The linear relationships, in the form of equation (B8), were poor, so only the optimum value of q_s was employed in the flow estimation procedure.

Flow Model Results

The gains were estimated for each reach as described above and were then summed to the Zwergle station target flow value to calculate a flow at each of the downstream model locations. Flow model results for May are shown in Table B2. The model sites corresponding to the Questa, Fish Hatchery, and Red River at Mouth gage stations have estimated average daily streamflows that are within 10 percent of the target flow values shown in Table B1.

Table B2. Flow Model Results for May

Model Station	Location	Area (m^2)	Q/A cfs per m^2	Flow cfs
1	Zwergle Gage	25.7		49.6
	Goose Creek	5.5	1.039	5.7
	Placer Creek	2.4	1.039	2.5
	Bobcat Creek	5.8	1.039	6.0
	seepage	5	0.346	1.8
2	Above town of Red River	44.6		65.6
	Bitter Creek	10	1.039	10.4
	seepage	1.9	0.346	0.7
3	Below Bitter Creek	56.5		76.7
	Pioneer Creek	5.3	1.039	5.5
	seepage	8.9	0.346	3.1
4	Below town of Red River	70.7		85.3
	Haut n Taut Creek			0.0
	seepage	1.6	0.346	0.6
5	Junebug Campground	72.3		85.8
	Straight Creek			0.0
	Red River WWTP outfall			0.98
	seepage	1.9	0.346	0.7
6	Elephant Rock Camp	74.2		87.5
	Hansen Creek			0.0
	seepage	2.3	0.346	0.8

Table B2. Flow Model Results for May

Model Station	Location	Area (m^2)	Q/A cfs per m^2	Flow cfs
7	Below Hansen Creek	76.5		88.3
	seep#1	2.1	0.346	0.7
8	At Mine Boundary	78.6		89.0
	seepage	7.5	0.346	2.6
9	Above Portal	86.1		91.6
	seep#2	0.6	0.346	0.2
10	Above Columbine Creek	86.7		91.8
	Columbine Creek	15.5	1.039	16.1
	seep#3	1.5	0.346	0.5
11	Below Columbine Creek	103.7		108.4
	seep#4	3	0.346	1.0
12	Above Goathill Gulch	106.7		109.5
	seep#5	5.9	0.346	2.0
13	Eagle Rock Campground	112.6		111.5
	seep#6	0.4	0.346	0.1
14	Questa Gage	113		111.7
	Cabresto Creek	36.7		33.8
	seepage	6	0.395	2.4
15	Below Cabresto Creek	155.7		147.8
	Mine outfall			0.54
	seepage	19.6	0.395	7.7
16	Below Mine Outfall	175.3		156.1
	Fish Hatchery outfall			14.5
	seepage	9.7	0.395	3.8
17	Fish Hatchery Gage	185		174.4
	seepage	5	0.395	2.0
18	Mouth Gage	190		176.4

The estimated average daily streamflows for May (high flow) were used to calculate the TMDL for the Red River. Streamflow samples taken during the spring runnoff period of 1999 showed the highest aluminum and sediment loadings. Therefore, an implicit MOS, with respect to average conditions, is provided in the loading allowances.

References

U.S. Geological Survey. 2001. Surface-Water Data for USA. <http://water.usgs.gov/nwis/sw>

Appendix C: Aluminum Modeling Methodology

Aluminum geochemistry was investigated because dissolved aluminum does not appear to directly affect the biological functioning of the Red River (Appendix D). However, it is known that aluminum colloids and floc that are present may be one of the primary impacts to the trout species in the river (see Appendix D). These floc form primarily at acidic groundwater seeps along the north side of the river. No known acidic seeps occur on the south side of the river. Acidic seep areas are visible due to precipitation of white and red-colored mineral deposits and occasional growth of green algae near the seeps. All the acid seeps produce a prominent plume of white aluminum precipitate that coats the river substrate, in some cases for scores of yards in a downstream direction. It is these aluminum compounds, in solution or suspended in river water, that are largely responsible for producing the milky-blue color commonly observed in the river between the Molycorp Mine and the Fish Hatchery.

The chemistry of these aluminum compounds or phases, is complex because aluminum ions (Al^{3+}) readily form primary, secondary, and tertiary complexes with several anion species such as hydroxyl (OH^-), sulfate (SO_4^{2-}), chloride (Cl^-), and fluoride (F^-) (Nordstrom and Alpers, 1997; Nordstrom, 1982). In addition, there are several solid aluminum phases such as $AlOH(SO_4)$ (aluminum hydroxysulfate), AlOH (aluminum hydroxide), and $Al(OH)_3$ (Gibbsite) that may control aluminum solubility in Red River system. The dominant aluminum species (dissolved or solid) in the Red River are dependent upon three characteristics of the system: the groundwater pH, the surface water pH, and the fluoride content of the surface water. Groundwater and surface water were characterized based on previous studies dating back to 1965 and summarized in the March 2001, URS report. In addition, fluoride concentrations were measured in the watershed in March 2001. This compilation of data was used to perform aluminum speciation and complexation modeling of Red River groundwater and surface water using the geochemical models EQ3/6 and MINEQL+. These codes have been extensively tested and are fully supported by government and/or private code developers. The first results from the EQ3/6 modeling were very close to those from MINEQL+ so the remainder of the samples were processed using MINEQL+ in order to utilize the more rapid preprocessing and post processing capabilities.

Geochemical modeling requires a comprehensive assessment of the mass action and mass balance components of the system, because several dissolved constituents such as anionic species may enhance or suppress aluminum solubility. In order to make the comprehensive assessment of the system for the geochemical modeling, surface and groundwater chemistry data on samples collected from the major tributaries, drainage ditches, outfalls and aquifers within the Red River Basin were examined. This data includes comprehensive water sampling taken by the SWQB in 1999 of the Red River watershed (NMED, 1999), water and sediment sampling performed by the ONRT (Allen et. al., 1999), and other investigations that produced readily accessible data. The ONRT investigation focused primarily on the Molycorp Mine and the natural scar areas that occur along the middle reach of the Red River, from the Town of Red River to the Village of Questa.

The mechanism for precipitation of minerals/metals from the groundwater is controlled by changes in solubility. These solubility changes are brought about by increases in pH that are a result of dilution and reaction with near surface water as shown in Figure C1. In acidic groundwater, aluminum-sulfate and aluminum-hydroxysulfate minerals become more stable than common soil minerals such as gibbsite and kaolinite. When the pH rises above 5 or higher, because of mixing with near neutral pH waters, an aluminum-hydroxysulfate compound precipitates immediately (Nordstrom and Alpers, 1997; Nordstrom, 1982). Red River modeling results show that the groundwater at some locations is over saturated with respect to aluminum-hydroxysulfate at low pH, and the surface water is saturated with gibbsite at the higher pH; this is shown in Figure C2 and Figure C3, respectively. Hence, the highly acidic groundwater which forms beneath the scars (Figure C1) can dissolve and transport elevated concentrations of contaminants, but when the groundwater emerges and mixes with river water, the pH is raised and dissolved constituents begin to deposit.

The comparison of surface water and groundwater pH at several sites along the middle portion of the Red River is shown in Figure C4. River water pH ranges from approximately 6.6 to 8.1. The pH of groundwater not impacted by the scar areas on the south side of the river ranges from approximately 6.8 to 7.3. The pH of the impacted groundwater (north side of the river) as sampled from monitoring wells and seeps ranges from 3.1 to 5.3. This can be seen at station 7 (below Hansen Creek) where shallow groundwater on the north side has a pH near 3, but south of the river the pH is near 7 and similar to surface water.

Figure C5 illustrates the relationship between pH and aluminum concentrations. As shown in the figure, aluminum has a double solubility curve (it is soluble at both low and elevated pH values), and is therefore present as precipitated deposits on substrate and as dissolved and suspended aluminum compounds carried in river water (NMED, 1996). The impact of fluoride on the solubility of aluminum is demonstrated in Figure C5. Fluoride is present in the middle reaches of the river in concentrations from 0.2 up to 1.1 mg/L. The presence of fluoride enhances aluminum solubility significantly below pH 6.6. This sharp drop in solubility above pH 6.6 affects the transport of aluminum as depicted in the conceptual model (Figure C1). This occurs by allowing the aluminum species to stay in solution until very near the surface, then precipitating out as it completely mixes with the higher pH of the river water.

All of the surface water aluminum data collected by the SWQB in May, August, and October 1999 are contained in Table C1. In addition, Stiff diagrams of major ions were plotted for water samples collected during the three-season survey in 1999 (Figures C6 through C8). The Stiff diagrams along the upper reaches above Bitter Creek depict the river water as a calcium carbonate type. Surface water in the middle reach of the Red River is characterized as calcium sulfate type, which indicates that contributions from ARD are mixing with the calcium carbonate water. Figures C6 through C8 show that the concentrations of major dissolved ions increased during spring runoff (i.e. the size of the plot increases for May 10, 1999 in Figure C6). However the overall water quality characteristics, as indicated by the general shape of the Stiff plot, does not change seasonally.

Table C1. Red River Watershed 1999 Surface Water Aluminum Data

Sample Location	Date Sampled	Aluminum (mg/L)
Ditch Cabin (RR01)		
NMED 1999	8/17/99	<0.01
NMED 1999	8/18/99	0.03
NMED 1999	10/25/99	0.02
NMED 1999	10/26/99	0.03
NMED 1999	10/27/99	0.03
NMED 1999	10/28/99	0.03
Upper Subdivision (RR03)		
NMED 1999	5/10/99	0.03
NMED 1999	5/10/99	0.36 (total)
NMED 1999	5/11/99	0.06
NMED 1999	5/11/99	0.40 (total)
NMED 1999	5/12/99	0.07
NMED 1999	5/12/99	0.17 (total)
NMED 1999	5/13/99	0.05
NMED 1999	5/13/99	0.22 (total)
Black Copper Canyon (RR04)		
NMED 1999	5/10/99	2.5
NMED 1999	5/25/99	0.7
NMED 1999	5/25/99	1.1 (total)
NMED 1999	5/26/99	0.46
NMED 1999	5/26/99	1.1 (total)
NMED 1999	5/27/99	0.6
NMED 1999	5/27/99	1.0 (total)
NMED 1999	5/28/99	0.7
NMED 1999	5/28/99	0.9 (total)
NMED 1999	8/17/99	0.01
NMED 1999	8/18/99	0.04
NMED 1999	10/25/99	0.03
NMED 1999	10/26/99	0.04
NMED 1999	10/27/99	0.04
NMED 1999	10/28/99	0.03
Red River at Zwergle Dam (RR06)		
NMED 1999	5/10/99	0.41
NMED 1999	5/10/99	1.4 (total)
NMED 1999	5/11/99	0.32
NMED 1999	5/11/99	1.1 (total)
NMED 1999	5/12/99	0.14
NMED 1999	5/12/99	0.50 (total)
NMED 1999	5/13/99	0.11
NMED 1999	5/13/99	0.50 (total)

Table C1. Red River Watershed 1999 Surface Water Aluminum Data

Sample Location	Date Sampled	Aluminum (mg/L)
Red River at Zwergle Dam (RR06) (cont.)		
NMED 1999	8/17/99	<0.01
NMED 1999	8/18/99	0.02
NMED 1999	8/18/99	0.09 (total)
NMED 1999	10/25/99	0.02
NMED 1999	10/25/99	0.06 (total)
NMED 1999	10/26/99	0.02
NMED 1999	10/26/99	0.05 (total)
NMED 1999	10/27/99	0.03
NMED 1999	10/27/99	0.05 (total)
NMED 1999	10/28/99	0.03
NMED 1999	10/28/99	0.05 (total)
Below Goose Creek (RR07)		
NMED 1999	5/10/99	0.21
NMED 1999	5/25/99	0.45
NMED 1999	5/25/99	0.80 (total)
NMED 1999	5/26/99	0.17
NMED 1999	5/26/99	0.60 (total)
NMED 1999	5/27/99	0.19
NMED 1999	5/27/99	0.43 (total)
NMED 1999	5/28/99	0.08
NMED 1999	5/28/99	0.40 (total)
NMED 1999	8/17/99	<0.01
NMED 1999	8/18/99	0.03
NMED 1999	10/25/99	0.02
NMED 1999	10/26/99	0.03
NMED 1999	10/27/99	0.03
NMED 1999	10/28/99	0.03
Bobcat Creek (RR08)		
NMED 1999	5/10/99	2.7
NMED 1999	8/17/99	<0.01
NMED 1999	8/18/99	0.03
NMED 1999	10/25/99	0.02
NMED 1999	10/26/99	0.02
NMED 1999	10/27/99	0.03
NMED 1999	10/28/99	0.11
Placer Creek (RR09)		
NMED 1999	5/10/99	1.1
NMED 1999	5/11/99	1.0
NMED 1999	5/12/99	1.4
NMED 1999	5/13/99	0.80
NMED 1999	8/17/99	<0.01

Table C1. Red River Watershed 1999 Surface Water Aluminum Data

Sample Location	Date Sampled	Aluminum (mg/L)
Placer Creek (RR09) (cont.)		
NMED 1999	8/18/99	0.03
NMED 1999	10/25/99	0.02
NMED 1999	10/26/99	0.03
NMED 1999	10/27/99	0.03
NMED 1999	10/28/99	0.02
Bitter Creek (RR10)		
NMED 1999	5/10/99	0.39
NMED 1999	5/11/99	1.2
NMED 1999	5/12/99	1.8
NMED 1999	5/13/99	0.80
NMED 1999	8/17/99	0.04
NMED 1999	8/18/99	0.06
NMED 1999	10/25/99	0.04
NMED 1999	10/26/99	0.33
NMED 1999	10/27/99	0.04
NMED 1999	10/28/99	0.03
Red River below Bitter Creek (RR11)		
NMED 1999	5/10/99	1.5
NMED 1999	5/10/99	5.4 (total)
NMED 1999	5/11/99	1.1
NMED 1999	5/11/99	4.4 (total)
NMED 1999	5/12/99	1.4
NMED 1999	5/12/99	3.1 (total)
NMED 1999	5/13/99	0.74
NMED 1999	5/13/99	2.9 (total)
NMED 1999	8/17/99	<0.01
NMED 1999	8/17/99	0.09 (total)
NMED 1999	8/18/99	0.03
NMED 1999	8/18/99	0.10 (total)
NMED 1999	10/25/99	0.02
NMED 1999	10/25/99	0.16 (total)
NMED 1999	10/26/99	0.02
NMED 1999	10/26/99	0.05 (total)
NMED 1999	10/27/99	0.03
NMED 1999	10/27/99	0.07 (total)
NMED 1999	10/28/99	0.03
NMED 1999	10/28/99	0.04 (total)
Mallette Creek (RR12)		
NMED 1999	5/10/99	1.4
NMED 1999	8/17/99	0.05
NMED 1999	8/18/99	0.07

Table C1. Red River Watershed 1999 Surface Water Aluminum Data

Sample Location	Date Sampled	Aluminum (mg/L)
Mallette Creek (RR12) (cont.)		
NMED 1999	10/25/99	0.03
NMED 1999	10/26/99	0.03
NMED 1999	10/27/99	0.03
NMED 1999	10/28/99	0.03
Pioneer Creek (RR13)		
NMED 1999	5/10/99	0.08
NMED 1999	5/25/99	0.09
NMED 1999	5/25/99	1.1 (total)
NMED 1999	5/26/99	0.08
NMED 1999	5/26/99	0.60 (total)
NMED 1999	5/27/99	0.10
NMED 1999	5/27/99	0.39 (total)
NMED 1999	5/28/99	0.08
NMED 1999	5/28/99	0.34 (total)
NMED 1999	8/17/99	0.05
NMED 1999	8/18/99	0.07
NMED 1999	10/25/99	0.06
NMED 1999	10/26/99	0.05
NMED 1999	10/27/99	0.07
NMED 1999	10/28/99	0.05
Junebug Campground (RR15)		
NMED 1999	5/10/99	1.5
NMED 1999	5/11/99	0.47
NMED 1999	5/12/99	0.31
NMED 1999	5/13/99	0.50
NMED 1999	8/17/99	0.10
NMED 1999	8/18/99	0.13
NMED 1999	10/25/99	0.11
NMED 1999	10/26/99	0.10
NMED 1999	10/27/99	0.10
NMED 1999	10/28/99	0.11
Straight Creek (RR16)		
NMED 1999	5/10/99	33
NMED 1999	5/11/99	33
Red River above RR WWTP (RR17)		
NMED 1999	5/10/99	0.30
NMED 1999	5/11/99	0.69
NMED 1999	5/12/99	0.60
NMED 1999	5/13/99	0.73
NMED 1999	8/17/99	0.11
NMED 1999	8/18/99	0.13

Table C1. Red River Watershed 1999 Surface Water Aluminum Data

Sample Location	Date Sampled	Aluminum (mg/L)
Red River above RR WWTP (RR17) (cont.)		
NMED 1999	10/25/99	0.11
NMED 1999	10/26/99	0.10
NMED 1999	10/27/99	0.10
NMED 1999	10/28/99	0.10
Red River below RR WWTP (RR18)		
NMED 1999	5/10/99	0.60
NMED 1999	5/11/99	0.90
NMED 1999	5/12/99	1.0
NMED 1999	5/13/99	1.0
NMED 1999	8/17/99	0.11
NMED 1999	8/18/99	0.13
NMED 1999	10/25/99	0.11
NMED 1999	10/26/99	0.09
NMED 1999	10/27/99	0.10
NMED 1999	10/28/99	0.11
Hansen Creek (RR19)		
NMED 1999	5/10/99	78
NMED 1999	5/11/99	89
NMED 1999	5/12/99	90
NMED 1999	5/13/99	91
Red River below Hansen Creek (RR20)		
NMED 1999	5/10/99	0.70
NMED 1999	5/10/99	6.3 (total)
NMED 1999	5/11/99	0.70
NMED 1999	5/11/99	2.5 (total)
NMED 1999	5/12/99	0.70
NMED 1999	5/12/99	2.0 (total)
NMED 1999	5/13/99	0.57
NMED 1999	5/13/99	2.0 (total)
NMED 1999	8/17/99	0.22
NMED 1999	8/17/99	0.90 (total)
NMED 1999	8/18/99	0.25
NMED 1999	8/18/99	0.70 (total)
NMED 1999	10/25/99	0.18
NMED 1999	10/25/99	0.60 (total)
NMED 1999	10/26/99	0.19
NMED 1999	10/26/99	0.60 (total)
NMED 1999	10/27/99	0.14
NMED 1999	10/27/99	0.60 (total)
NMED 1999	10/28/99	0.19
NMED 1999	10/28/99	0.70 (total)

Table C1. Red River Watershed 1999 Surface Water Aluminum Data

Sample Location	Date Sampled	Aluminum (mg/L)
Red River at Molycorp boundary (RR21)		
NMED 1999	5/10/99	0.60
NMED 1999	5/11/99	1.0
NMED 1999	5/12/99	0.72
NMED 1999	5/13/99	0.64
NMED 1999	8/17/99	0.19
NMED 1999	8/18/99	0.22
NMED 1999	10/25/99	0.12
NMED 1999	10/26/99	0.11
NMED 1999	10/27/99	0.12
NMED 1999	10/28/99	0.13
Red River above Seep #2 (RR22)		
NMED 1999	5/10/99	0.40
NMED 1999	5/11/99	0.60
NMED 1999	5/12/99	0.45
NMED 1999	5/13/99	0.62
NMED 1999	8/17/99	0.19
NMED 1999	8/18/99	0.22
NMED 1999	10/25/99	0.12
NMED 1999	10/26/99	0.10
NMED 1999	10/27/99	0.10
NMED 1999	10/28/99	0.15
Red River above Columbine Creek (RR23)		
NMED 1999	5/10/99	0.70
NMED 1999	5/11/99	0.50
NMED 1999	5/12/99	0.47
NMED 1999	5/13/99	0.49
NMED 1999	8/17/99	0.20
NMED 1999	8/18/99	0.21
NMED 1999	10/25/99	0.13
NMED 1999	10/26/99	0.12
NMED 1999	10/27/99	0.13
NMED 1999	10/28/99	0.14
Columbine Creek (RR24)		
NMED 1999	5/10/99	0.50
NMED 1999	5/11/99	0.58
NMED 1999	5/12/99	0.20
NMED 1999	5/13/99	0.30
NMED 1999	8/17/99	<0.01
NMED 1999	8/18/99	0.02
NMED 1999	10/25/99	<0.01
NMED 1999	10/26/99	<0.01

Table C1. Red River Watershed 1999 Surface Water Aluminum Data

Sample Location	Date Sampled	Aluminum (mg/L)
Columbine Creek (RR24) (cont.)		
NMED 1999	10/27/99	<0.01
NMED 1999	10/28/99	0.02
Red River below Columbine Creek (RR25)		
NMED 1999	5/10/99	0.45
NMED 1999	5/11/99	0.80
NMED 1999	5/12/99	0.44
NMED 1999	5/13/99	0.60
NMED 1999	8/17/99	0.17
NMED 1999	8/18/99	0.18
NMED 1999	10/25/99	0.09
NMED 1999	10/25/99	0.50 (total)
NMED 1999	10/26/99	0.09
NMED 1999	10/26/99	0.50 (total)
NMED 1999	10/27/99	0.10
NMED 1999	10/27/99	0.53 (total)
NMED 1999	10/28/99	0.13
NMED 1999	10/28/99	0.57 (total)
Red River below Seep #3 (RR26)		
NMED 1999	5/10/99	0.70
NMED 1999	5/11/99	0.46
NMED 1999	5/12/99	0.56
NMED 1999	5/13/99	0.55
NMED 1999	8/17/99	0.25
NMED 1999	8/18/99	0.27
NMED 1999	10/25/99	0.11
NMED 1999	10/26/99	0.09
NMED 1999	10/27/99	0.11
NMED 1999	10/28/99	0.30
Red River above Goat Hill Gulch (RR27)		
NMED 1999	5/10/99	0.50
NMED 1999	5/11/99	0.25
NMED 1999	5/12/99	0.50
NMED 1999	5/13/99	0.47
NMED 1999	8/17/99	0.25
NMED 1999	8/18/99	0.26
NMED 1999	10/25/99	0.13
NMED 1999	10/26/99	0.13
NMED 1999	10/27/99	0.13
NMED 1999	10/28/99	0.13

Table C1. Red River Watershed 1999 Surface Water Aluminum Data

Sample Location	Date Sampled	Aluminum (mg/L)
Red River above Capulin Creek (RR28)		
NMED 1999	5/10/99	0.23
NMED 1999	5/11/99	0.29
NMED 1999	5/12/99	0.40
NMED 1999	5/13/99	0.47
NMED 1999	8/17/99	0.31
NMED 1999	8/18/99	0.32
NMED 1999	10/25/99	0.22
NMED 1999	10/26/99	0.21
NMED 1999	10/27/99	0.20
NMED 1999	10/28/99	0.21
Red River below Capulin Creek (RR29)		
NMED 1999	5/10/99	0.15
NMED 1999	5/11/99	0.14
NMED 1999	5/12/99	0.42
NMED 1999	5/13/99	0.35
NMED 1999	8/17/99	0.29
NMED 1999	8/17/99	1.3 (total)
NMED 1999	8/18/99	0.28
NMED 1999	8/18/99	1.3 (total)
NMED 1999	10/25/99	0.16
NMED 1999	10/25/99	1.4 (total)
NMED 1999	10/26/99	0.15
NMED 1999	10/26/99	1.5 (total)
NMED 1999	10/27/99	0.16
NMED 1999	10/27/99	1.7 (total)
NMED 1999	10/28/99	0.19
NMED 1999	10/28/99	1.5 (total)
Red River at Questa Gage (RR31)		
NMED 1999	5/10/99	0.33
NMED 1999	5/10/99	4.9 (total)
NMED 1999	5/11/99	0.60
NMED 1999	5/11/99	3.4 (total)
NMED 1999	5/12/99	0.42
NMED 1999	5/12/99	3.0 (total)
NMED 1999	5/13/99	0.37
NMED 1999	5/13/99	2.6 (total)
NMED 1999	8/17/99	0.31
NMED 1999	8/18/99	0.26
NMED 1999	10/25/99	0.17
NMED 1999	10/26/99	0.15

Table C1. Red River Watershed 1999 Surface Water Aluminum Data

Sample Location	Date Sampled	Aluminum (mg/L)
Red River at Questa Gage (RR31) (cont.)		
NMED 1999	10/27/99	0.15
NMED 1999	10/28/99	0.17
Cabresto Creek (RR32)		
NMED 1999	5/10/99	0.14
NMED 1999	5/11/99	0.29
NMED 1999	5/12/99	0.12
NMED 1999	5/13/99	0.10
Cabresto Creek (RR32) (cont.)		
NMED 1999	8/17/99	0.05
NMED 1999	8/18/99	0.07
NMED 1999	10/25/99	<0.01
NMED 1999	10/26/99	<0.01
NMED 1999	10/27/99	<0.01
NMED 1999	10/28/99	0.02
Red River above Questa WWTP (RR33)		
NMED 1999	5/10/99	0.30
NMED 1999	5/11/99	0.29
NMED 1999	5/12/99	0.35
NMED 1999	5/13/99	0.50
NMED 1999	8/17/99	0.24
NMED 1999	8/18/99	0.22
NMED 1999	10/25/99	0.11
NMED 1999	10/26/99	0.10
NMED 1999	10/27/99	0.10
NMED 1999	10/28/99	0.11
Red River below Questa WWTP (RR34)		
NMED 1999	5/10/99	0.22
NMED 1999	5/11/99	0.45
NMED 1999	5/12/99	0.58
NMED 1999	5/13/99	0.35
NMED 1999	8/17/99	0.21
NMED 1999	8/18/99	0.20
NMED 1999	10/25/99	0.11
NMED 1999	10/26/99	0.08
NMED 1999	10/27/99	0.09
NMED 1999	10/28/99	0.11
Red River below outfall 002 (RR35)		
NMED 1999	5/10/99	0.30
NMED 1999	5/11/99	0.22
NMED 1999	5/12/99	0.36
NMED 1999	5/13/99	0.47

Table C1. Red River Watershed 1999 Surface Water Aluminum Data

Sample Location	Date Sampled	Aluminum (mg/L)
Red River below outfall 002 (RR35) (cont.)		
NMED 1999	8/17/99	0.17
NMED 1999	8/18/99	0.16
NMED 1999	10/25/99	0.08
NMED 1999	10/25/99	0.96 (total)
NMED 1999	10/26/99	0.07
NMED 1999	10/27/99	0.07
NMED 1999	10/27/99	1.0 (total)
NMED 1999	10/28/99	0.09
NMED 1999	10/28/99	1.1 (total)
Red River at Fish Hatchery Gage (RR37)		
NMED 1999	5/10/99	0.30
NMED 1999	5/10/99	8.0 (total)
NMED 1999	5/11/99	0.20
NMED 1999	5/12/99	0.31
NMED 1999	5/13/99	0.23
NMED 1999	8/17/99	0.14
NMED 1999	8/17/99	0.60 (total)
NMED 1999	8/18/99	0.16
NMED 1999	8/18/99	0.60 (total)
NMED 1999	10/25/99	0.07
NMED 1999	10/25/99	0.70 (total)
NMED 1999	10/26/99	0.06
NMED 1999	10/26/99	0.53 (total)
NMED 1999	10/27/99	0.07
NMED 1999	10/27/99	0.60 (total)
NMED 1999	10/28/99	0.10
NMED 1999	10/28/99	0.57 (total)

In order to use a biological assessment of aluminum loading effects along the middle portion of the Red River a loading model was developed that coupled the Red River Watershed flow model with available water chemistry data. The model estimates the amount of aluminum loading occurring from groundwater seepage and tributary inputs. Aluminum data that was used to calculate aluminum loads for TMDL development are contained in Table C2 and Table C3. A portion of this data is also shown in Figure 6. Data presented in Table C2 was collected in 1999 by the SWQB as part of their three-season intensive survey.

Table C2. Surface Water Aluminum Data from 1999 for Loading Model

Location Source	**Date Sampled**	**Aluminum (mg/L)**
Goose Creek (RR07)+		
NMED 1999	5/10/99	0.21
NMED 1999	5/25/99	0.45
NMED 1999	5/25/99	0.80 (total) *
NMED 1999	5/26/99	0.17
NMED 1999	5/26/99	0.6 (total)
NMED 1999	5/27/99	0.19
NMED 1999	5/27/99	0.43 (total)
NMED 1999	5/28/99	0.08
NMED 1999	5/28/99	0.40 (total)
	Average	***0.37***
Placer Creek (RR09)		
NMED 1999	5/10/99	1.1
NMED 1999	5/11/99	1.0
NMED 1999	5/12/99	1.4 *
NMED 1999	5/13/99	0.80
	Average	***1.08***
Bobcat Creek (RR08)		
NMED 1999	5/10/99	2.7 *
	Average	***2.7***
Bitter Creek (RR10)		
NMED 1999	5/10/99	0.39
NMED 1999	5/11/99	1.2
NMED 1999	5/12/99	1.8 *
NMED 1999	5/13/99	0.80
	Average	***1.05***
Pioneer Creek (RR13)		
NMED 1999	5/10/99	0.08
NMED 1999	5/25/99	0.09
NMED 1999	5/25/99	1.1 (total) *
NMED 1999	5/26/99	0.08
NMED 1999	5/26/99	0.6 (total)
NMED 1999	5/27/99	0.10
NMED 1999	5/27/99	0.39 (total)
NMED 1999	5/28/99	0.08
NMED 1999	5/28/99	0.34 (total)
	Average	***0.32***
Cabresto Creek (RR32)		
NMED 1999	5/10/99	0.14
NMED 1999	5/11/99	0.29*

Table C2. Surface Water Aluminum Data from 1999 for Loading Model

Location Source	Date Sampled	Aluminum (mg/L)
Cabresto Creek (RR32) (cont.)		
NMED 1999	5/12/99	0.12
NMED 1999	5/13/99	0.10
	Average	***0.16***
Upper Red River (Station 1 - Red River at Zwergle Dam RR06)		
NMED 1999	5/10/99	1.4 (total) *
NMED 1999	5/10/99	0.41
NMED 1999	5/11/99	1.1 (total)
NMED 1999	5/11/99	0.32
NMED 1999	5/12/99	0.14
NMED 1999	5/12/99	0.50 (total)
NMED 1999	5/13/99	0.50 (total)
NMED 1999	5/13/99	0.11
	Average	***0.56***
Middle Red River (Station 14 - Red River at Questa Gage RR31)		
NMED 1999	5/10/99	0.33
NMED 1999	5/10/99	4.9 (total) *
NMED 1999	5/11/99	0.6
NMED 1999	5/11/99	3.4 (total)
NMED 1999	5/12/99	0.42
NMED 1999	5/12/99	3.0 (total)
NMED 1999	5/13/99	0.37
NMED 1999	5/13/99	2.6 (total)
	Average	***1.95***
Lower Red River (Station 17 - Red River at Fish Hatchery Gage RR37)		
NMED 1999	5/10/99	0.30
NMED 1999	5/10/99	8.0 (total) *
NMED 1999	5/11/99	0.20
NMED 1999	5/12/99	0.31
NMED 1999	5/13/99	0.23
	Average	***1.81***

[+]This site is actually located on the Red River below Goose Creek, but assumed to be similar to Goose Creek and groundwater seepage between flow model stations 1 and 2.

*Highest concentrations were used to calculate measured loads in Table C6.

Table C3. Reference Groundwater Aluminum Data for Loading Model

TMDL Flow Model Station Source	Date Sampled	Aluminum (mg/L)
3 - Below Bitter Creek		
NMED 1996, #28	8/24/93	9.9 *
	Average	***9.9***
4 - Below Red River		
NMED 1996, #30	9/8/93	0.4 *
	Average	***0.4***
5 - Junebug Campground		
NMED 1996, #26	8/24/93	<0.1 * +
Vail 2000, Table 2	11/8/94	<0.028 +
	Average	***0.032***
6 - Elephant Rock Campground		
NMED 1996, #25	8/24/93	<0.1 * +
Vail 2000, Table 2	11/8/94	<0.028 +
	Average	***0.032***
7 - Seep #1 Below Hansen Creek		
NMED 1996, #45	5/4/94	86 *
	Average	***86***
8 - At Mine Boundary		
URS 2001, MMW-17B	1/00	11 *
	Average	***11***
9 - Seep #2 Sulphur Gulch		
NMED 1996, # 20, S-4	8/24/93	0.6
NMED 1996, # 32, S-5	9/9/93	1.2 *
	Average	***0.9***
10 - Seep #3 Portal Springs		
Vail 2000, Table 2	6/15/00	16
NMED 1996, #40, S-13a	2/3/94	24
NMED 1996, #41, S-13b	2/3/94	13
URS 2001	5/94	21.3
URS 2001	10/95	27.6
Vail 2000, Table 2	2/3/00	64 *
Vail 2000, Table 2	2/3/00	19
	Average	***26.4***
11 - Seep #4 Cabin Springs		
URS 2001	9/92	22.1
URS 2001	2/94	30.4
Vail 2000, Table 2	6/00	48
URS 2001	10/95	33
	Average	***33.4***

Table C3. Reference Groundwater Aluminum Data for Loading Model

TMDL Flow Model Station Source	Date Sampled	Aluminum (mg/L)
12 - Seep # 5 Above Goathill Gulch		
NMED 1996, # 39, S-12	9/21/93	36
	Average	***36***
13 - Seep # 6 Capulin Canyon		
NMED 1996, # 39, S-10	9/21/93, 5/4/94, 8/2/94, 7/8/92, 2/21/95	130, 120, 120, 130, 150
NMED 1996, # 38, S-11	9/21/93	65.0
NMED 1996, # 36, S-9	9/21/93	140.0
NMED 1996, # 35, S-8	9/21/93	180.0
NMED 1996, # 34, S-7	9/21/93	96.0
	Average	***122***
14 - Seep # 7 Above Ranger Station		
NMED 1996, # 18, S-1	8/24/93	100.0
NMED 1996, # 19, S-2	8/24/93	100.0
	Average	***100***

NOTE: NMED 1996 data from Table 1 as updated 3/18/96.
*Highest concentrations were used to calculate measured loads in Table C6.
+A value of one half the detection limit was used for analysis and calculations.

Results of the aluminum loading model for each sampling station and seep are contained in Table C4 and shown for a portion of the Red River in Figure 8. A discussion of the overall results is contained in the aluminum target loading section of the main TMDL document.

Table C4. Aluminum Loading along the Red River

TMDL Flow Model Station	Location Description	Flow + (mgd)	Average* Measured Concentration (mg/L)	Conversion Factor	Total Aluminum Loading (lb/day)
Upper Red River					
1	Former Zwergle Dam	32.0	0.56	8.34	149.5
	Goose Creek	3.7	0.37	8.34	11.42
	Bobcat Creek	3.9	2.7	8.34	87.8
Middle Red River					
	Placer Creek	1.6	1.08	8.34	14.41
2	Seepage (1 to 2)	1.16	0.37	8.34	3.6
	Bitter Creek	6.7	1.05	8.34	58.67
3	Seepage (2 to 3)	0.45	9.9	8.34	37.2
	Pioneer Creek	3.6	0.32	8.34	9.61
4	Seepage (3 to 4)	2.00	0.4	8.34	6.7
5	Junebug CG	0.39	0.032	8.34	0.10

Table C4. Aluminum Loading along the Red River

TMDL Flow Model Station	Location Description	Flow + (mgd)	Average* Measured Concentration (mg/L)	Conversion Factor	Total Aluminum Loading (lb/day)
Middle Red River (cont.)					
6	Elephant Rock CG	0.45	0.032	8.34	0.12
7	Seep #1 below Hansen Creek	0.52	86.0	8.34	373
8	Seepage (7 to 8)	0.45	11	8.34	41.3
9	Seep #2 above Portal Spring	1.68	0.9	8.34	12.6
10	Seep #3 above Columbine Creek	0.13	26.4	8.34	28.6
Lower Red River					
11	Seep #4 Cabin Springs	0.32	33.4	8.34	89.1
12	Seep #5 above Goathill Gulch	0.65	36.0	8.34	195
13	Seep #6 Capulin Canyon	1.29	122	8.34	1,312
14	Seep #7 above the Ranger Station	0.06	100	8.34	50

+ Flow values are groundwater seepage amounts from the Red River Watershed flow model for May.
* Calculated in Table C2 or C3

Target loads estimated for specific stations along the Middle Red River are presented in Table C5 and measured loads are contained in Table C6.

Table C5. Target Loads for the Middle Red River

TMDL Flow Model Station	Location Description	Flow + (mgd)	Standard Metals Dissolved Aluminum (mg/L)	Conversion Factor	Target Load Capacity (lbs/day)
Upper Red River					
1	Former Zwergle Dam	32.0	0.087	8.34	23.2
	Goose Creek	3.7	0.087	8.34	2.7
	Bobcat Creek	3.9	0.087	8.34	2.8
Middle Red River					
	Placer Creek	1.6	0.750	8.34	10
2	Seepage (1 to 2)	1.16	NA	8.34	50 *
	Bitter Creek	6.7	NA	8.34	50 *
3	Seepage (2 to 3)	0.45	NA	8.34	50 *
	Pioneer Creek	3.6	NA	8.34	50 *
4	Seepage (3 to 4)	2.00	NA	8.34	50 *
5	Junebug CG	0.39	NA	8.34	50 *
6	Elephant Rock CG	0.45	NA	8.34	50 *
7	Seep #1 below Hansen Creek	0.52	NA	8.34	50 *
8	Seepage (7 to 8)	0.45	NA	8.34	50 *

Table C5. Target Loads for the Middle Red River

TMDL Flow Model Station	Location Description	Flow + (mgd)	Standard Metals Dissolved Aluminum (mg/L)	Conversion Factor	Target Load Capacity (lbs/day)
Middle Red River (cont.)					
9	Seep #2 Portal Spring	1.68	NA	8.34	50 *
10	Seep #3 above Columbine Creek	0.13	NA	8.34	50 *
Total Cumulative Target Load					***588.7***

+ Flow values are groundwater seepage amounts from the Red River Watershed flow model for May.
* Target loading based on biological assessment.

Table C6. Measured Aluminum Loads for the Middle Red River

TMDL Flow Model Station	Location Description	Flow + (mgd)	Measured Concentration (mg/L)*	Conversion Factor	Total Aluminum Loading (lb/day)
Upper Red River					
1	Former Zwergle Dam	32.0	1.4	8.34	373.6
	Goose Creek	3.7	0.8	8.34	24.7
	Bobcat Creek	3.9	2.7	8.34	87.8
Middle Red River					
	Placer Creek	1.6	1.4	8.34	18.7
2	Seepage (1 to 2)	1.16	0.8	8.34	7.7
	Bitter Creek	6.7	1.8	8.34	100.6
3	Seepage (2 to 3)	0.45	9.9	8.34	37.2
	Pioneer Creek	3.6	1.1	8.34	33.0
4	Seepage (3 to 4)	2.00	0.4	8.34	6.7
5	Junebug CG	0.39	0.05	8.34	0.2
6	Elephant Rock CG	0.45	0.05	8.34	0.2
7	Seep #1 below Hansen Creek	0.52	86	8.34	373.0
8	Seepage (7 to 8)	0.45	11	8.34	41.3
9	Seep #2 Portal Spring	1.68	1.2	8.34	16.8
10	Seep #3 above Columbine Creek	0.13	64	8.34	69.4
				Total Cumulative Al Loading	***1,190.9***

+Flow values were estimated from Red River Watershed flow model for May.
*Peak concentrations were used as conservative values (See Tables C2 and C3).

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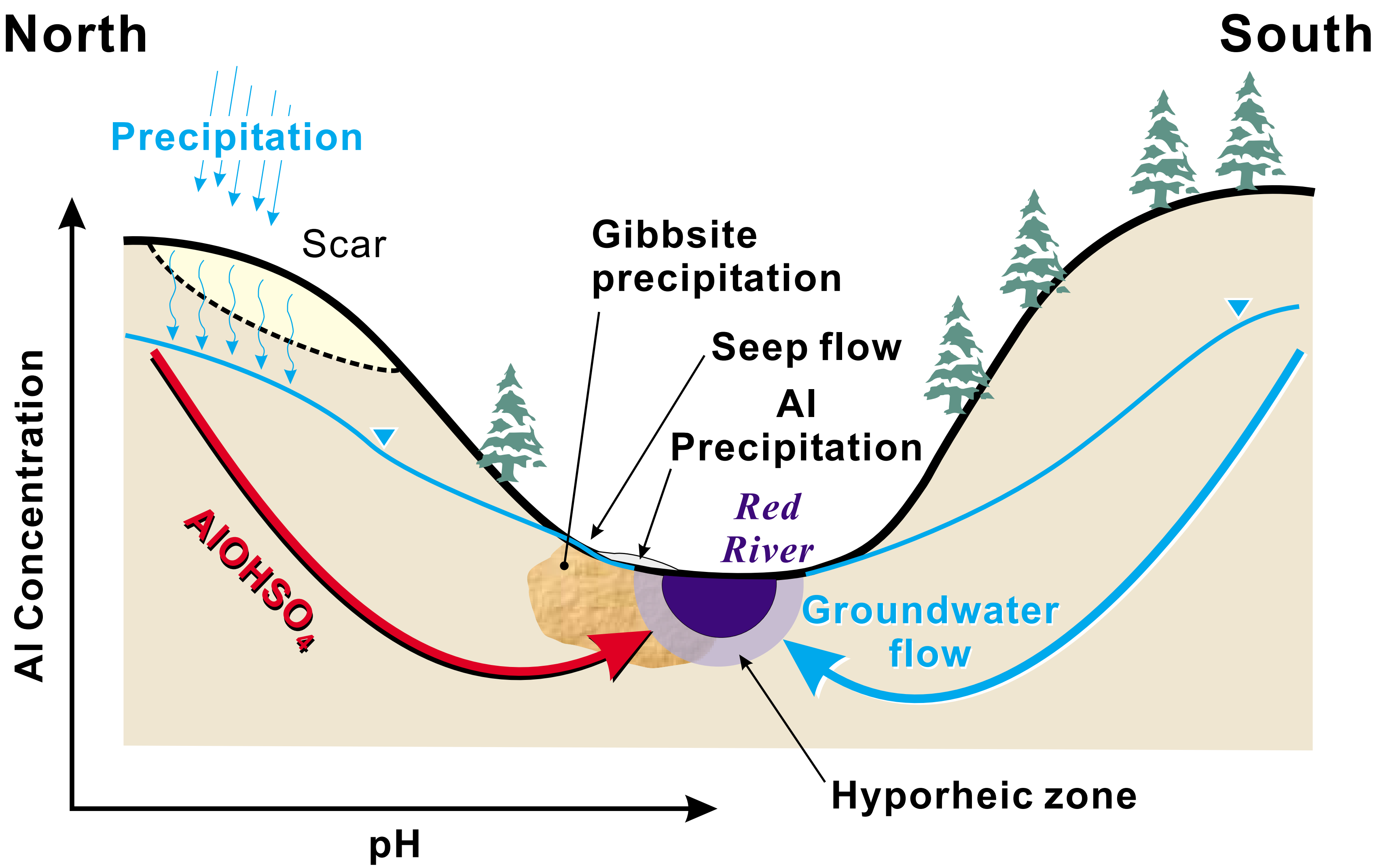


Not to Scale

RED RIVER TMDL

Conceptual Loading Model

Figure C1

01-09-02 JN 9253

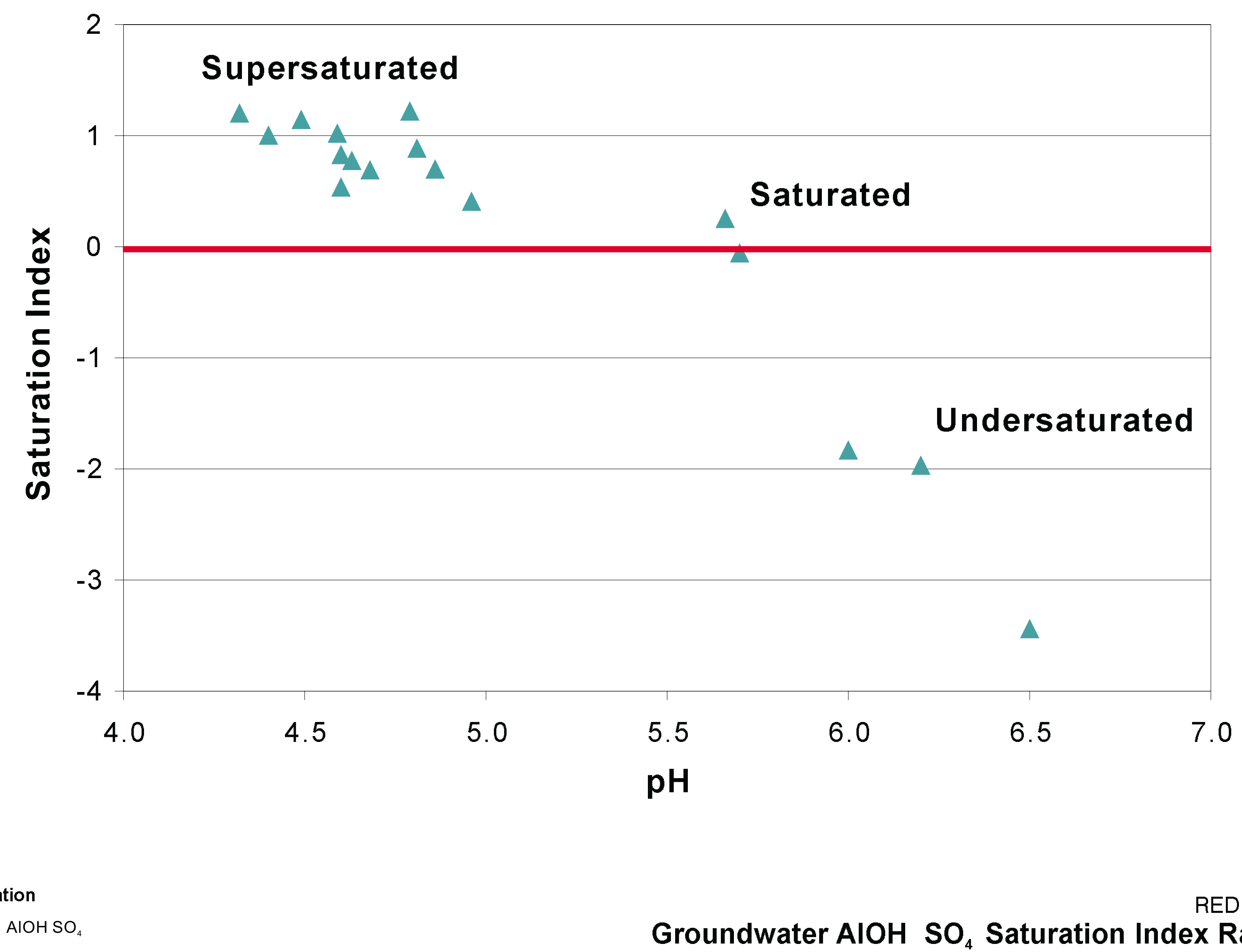
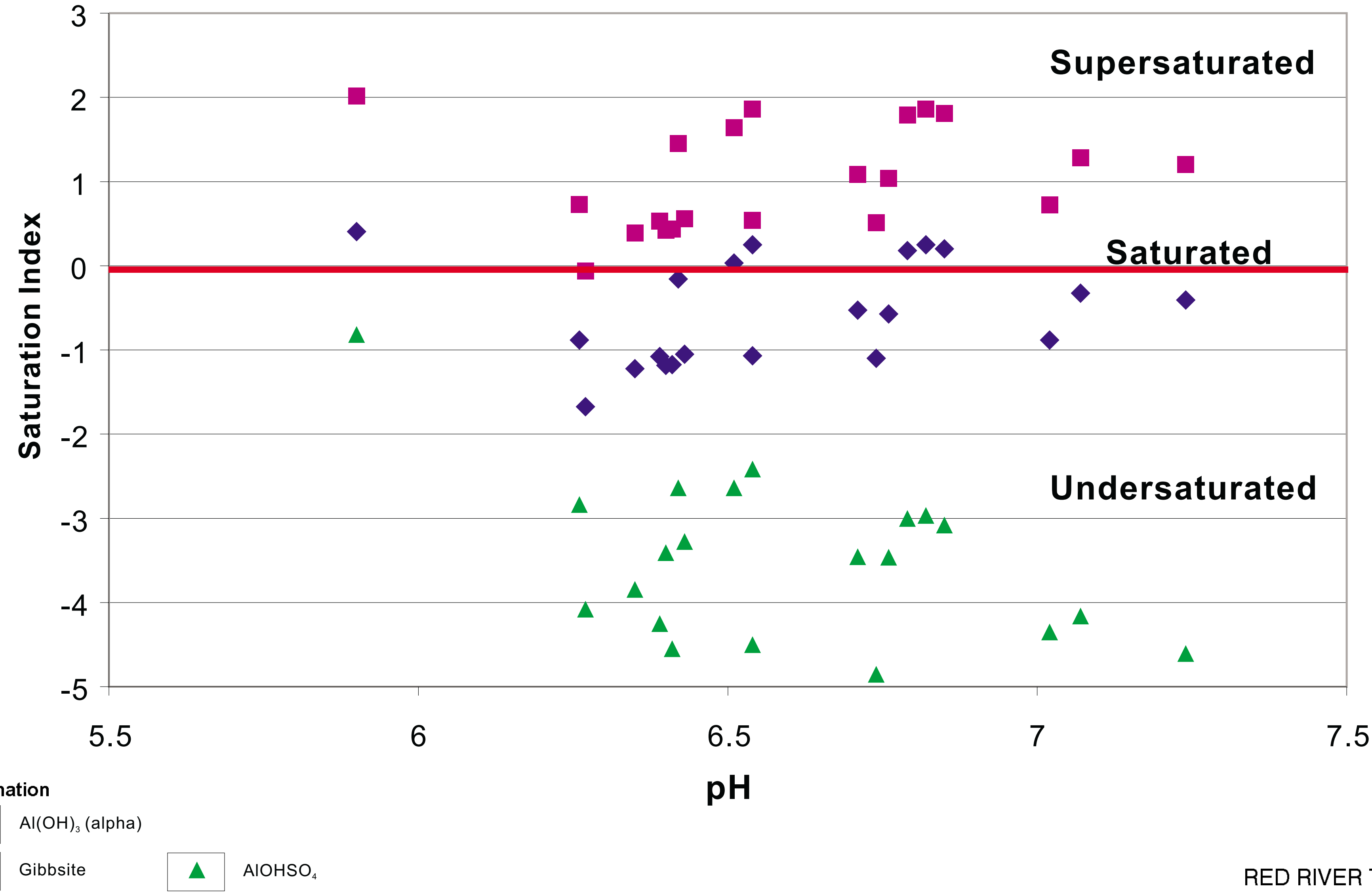


Figure C2

RED RIVER TMDL

Groundwater AlOH SO_4 Saturation Index Ratio vs pH

12-28-01 JN 9253



RED RIVER TMDL

Aluminum Species Saturation Index for Red River Surface Water Samples March 2001

Figure C3

12-28-01

JN 9253

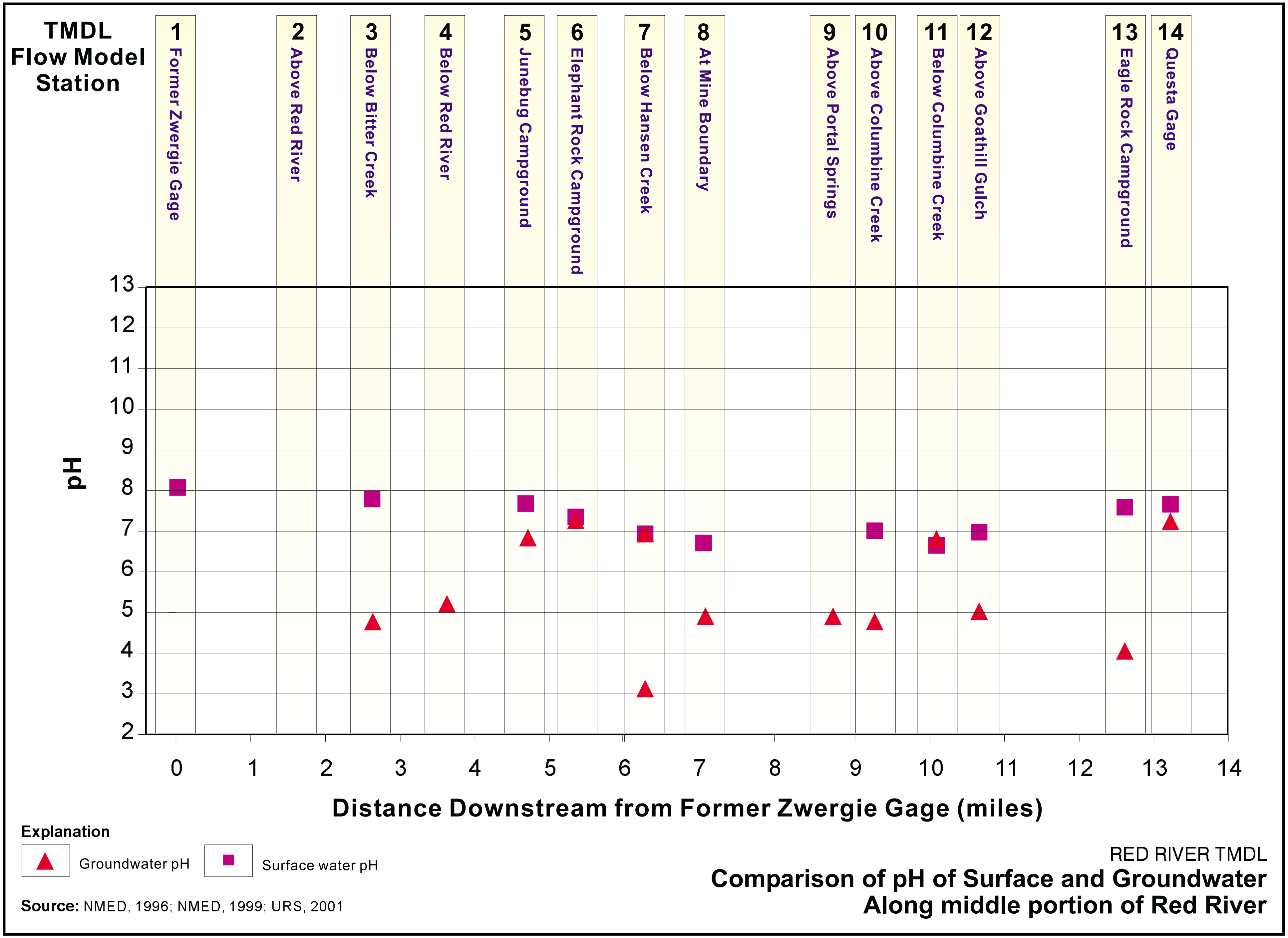
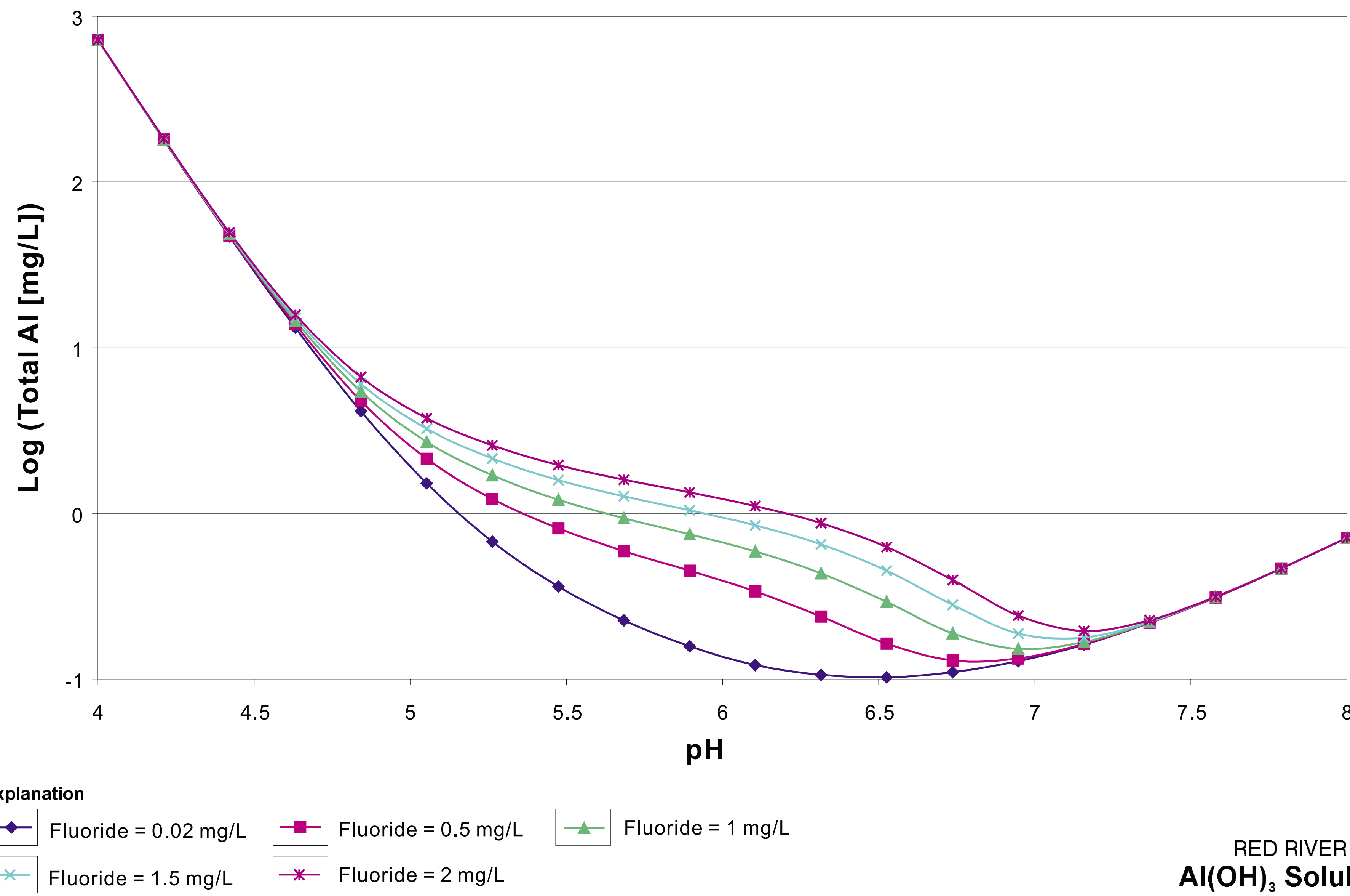


Figure C4

1-2-02 JN 9253

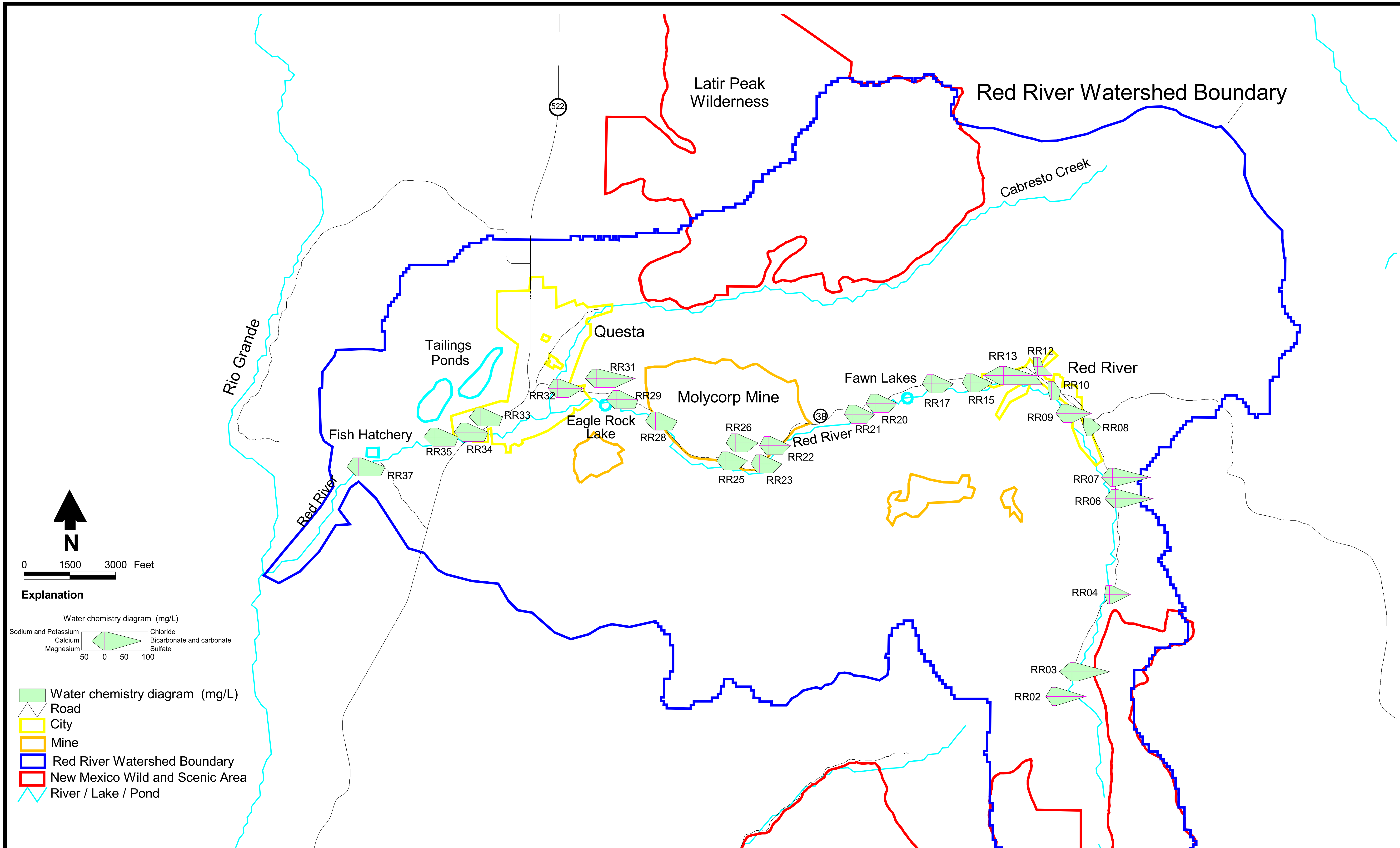


RED RIVER TMDL

$Al(OH)_3$ Solubility with Varying Fluoride Concentrations

Figure C5

12-28-01 JN 9253

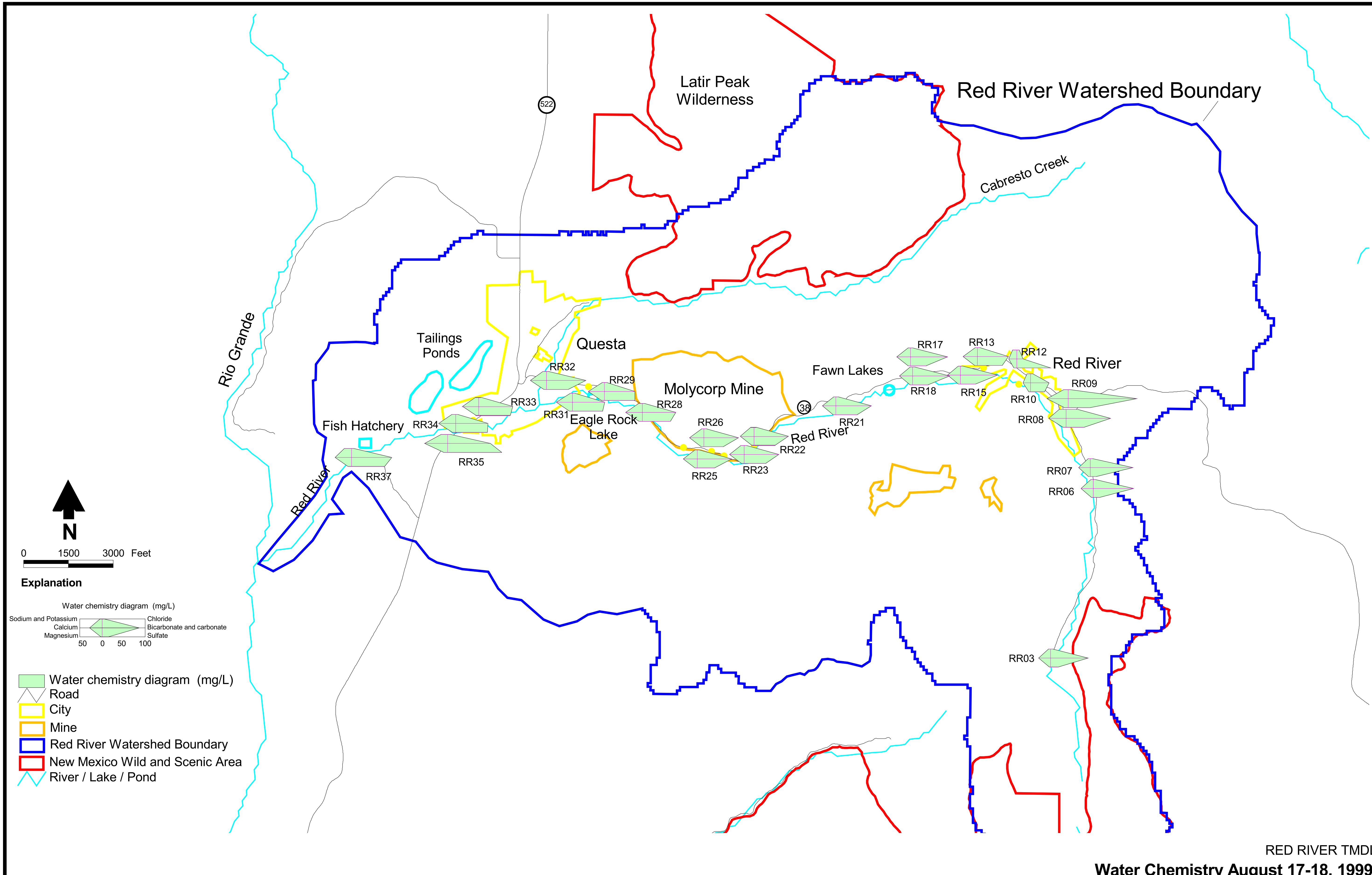


RED RIVER TMDL

Water Chemistry May 10, 1999

12/31/01

Figure C6

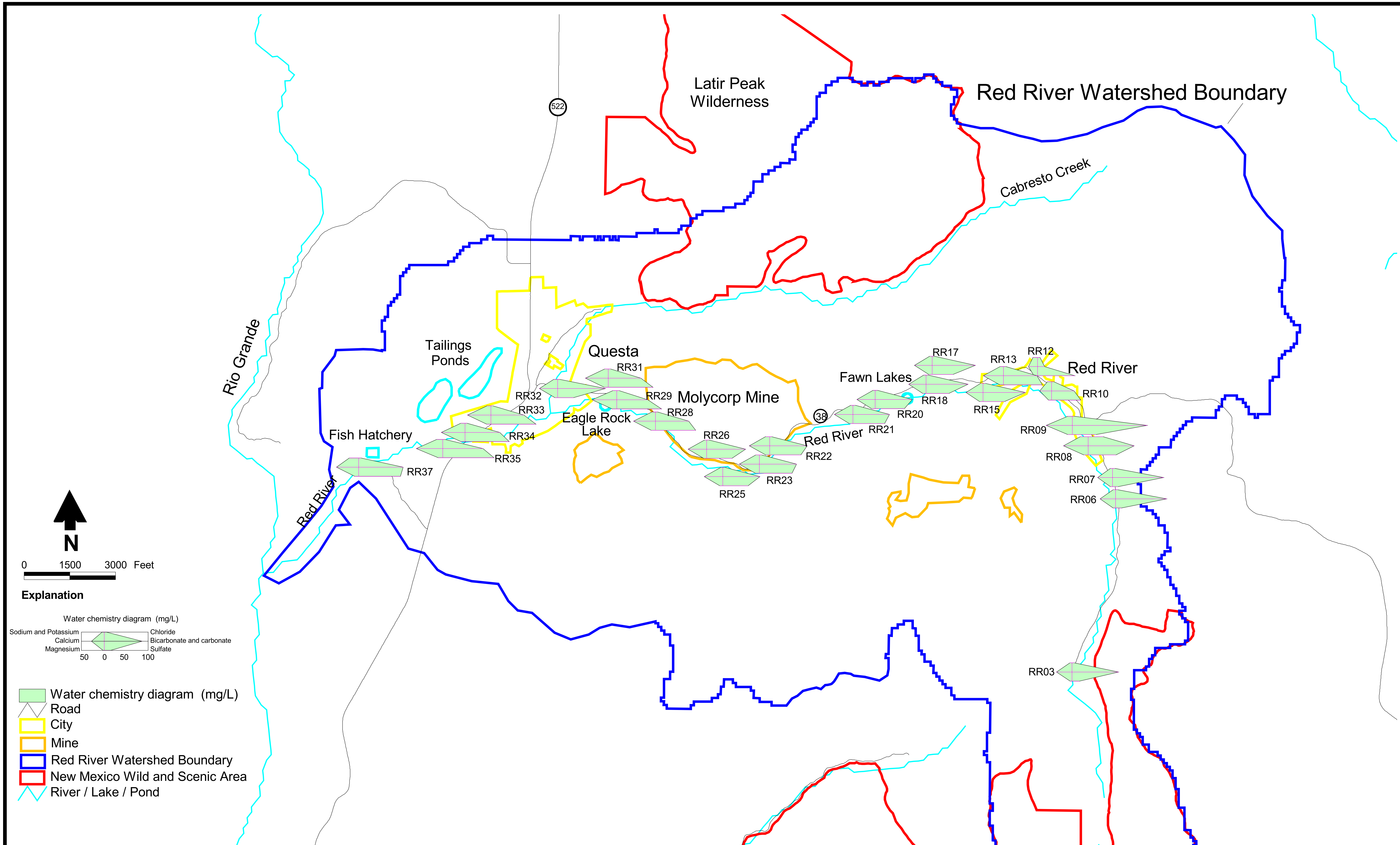


RED RIVER TMDL

Water Chemistry August 17-18, 1999

12/31/01

Figure C7



RED RIVER TMDL

Water Chemistry October 25, 1999

12/31/01

Figure C8

Appendix D: Biological Analyses

Introduction

The assessment of aquatic life relationships in the Red River for this TMDL was based on an assessment of existing data produced by a variety of previous studies on the aquatic life of the Red River. These include studies by Melancon et al. (1982), Akroyd (1988), Jacobi et al. (1998b), and particularly a series of studies for the Molycorp Questa Mine by Chadwick Ecological Consultants (Chadwick, 1997, 1998, 1999, 2000, 2001). This information shows that densities of trout, densities of benthic macroinvertebrates, and numbers of benthic macroinvertebrate taxa, are markedly greater (i.e., approximately 1.5- to 5-times greater) in recent samples, relative to samples from 1965-1992, especially for sites upstream of the Town of Red River. Also, Jacobi et al. (1998b) concluded that the data set developed by NMED from samples collected during December 1995 had numerous outliers and should be excluded from additional analyses. As a result, the data assessment for this TMDL focused on examining aquatic life relationships and establishing biological goals for the Red River watershed using the more recent data set developed by Chadwick.

Aquatic Populations in the Red River

Biological data collected by Chadwick (1997, 1998, 1999, 2000, 2001) for the Red River system are presented here in a series of plots for nine sampling sites along the mainstem of the Red River and three sampling sites on three tributaries of the Red River (Middle Fork of the Red River, Columbine Creek, and Cabresto Creek):

- Figures D-1 to D-7 show the data on fish density (numbers per mile of river) found at the sampling sites for all fish, brook trout, brown trout, cutthroat trout, rainbow trout, rainbow/cutthroat trout hybrids, and total non-RBT trout (all trout excluding rainbow trout, most of which are stocked into the Red River).

- Figures D-8 to D-14 show data on fish biomass (pounds per acre) at these sites for the same groupings of fish.

- Figure D-15 shows the body condition factor (K) for the five kinds of trout found in the Red River watershed for fish collected during the September 2000 sampling. Body condition is a general indicator of "fatness" and health of fish.

- Figures D-16 to D-20 show data for benthic macroinvertebrate communities (i.e., bottom-living aquatic invertebrates) found at the nine Red River and three tributary sampling sites found in samples collected between 1995 and 2000. Data presented for each sample site on each sample date include total densities (total number individuals per square meter of stream bottom); total number of taxa found per sample site; total number of EPT taxa per site (i.e., total number of three Orders of insect taxa generally found to be sensitive to pollutant effects, including Ephemeroptera – mayflies, Plecoptera – stoneflies, and Trichopter – caddisflies); percent of EPT taxa in the total population; and Shannon-Weiner diversity (H', a measure of number and proportional distribution of taxa in the sampled community that has been found to often correlate with pollution impacts).

- Figures D-21 and D-22 present the distribution along ten sites in the Red River drainage for three sensitive families of aquatic insects, which were characterized as sensitive within this ecoregion in the NM Index of Biotic Integrity (IBI) being developed by New Mexico Game and Fish (NMGF) (Jacobi et al., 1998a).

The sites on all 22 of these figures are arranged along their relative elevation gradient, with the highest altitude sites on the left and the lowest sites on the right. Also, these figures show data for the tributary sites enclosed in boxes included at their relative elevation positions. This is done to allow easy comparisons of data among sites with similar elevations; altitude is an important correlate for many factors naturally affecting biological communities (e.g., temperature, growing season length).

Major trends shown by the data across the five to six years of studies shown in these plots are summarized in the following.

- From the Middle Fork of Red River to June Bug Campground, trout numbers and biomass, and benthic macroinvertebrate numbers and diversity generally show trends of decrease by 30-70%, or more; brook trout essentially drop out of the population, brown trout densities and biomasses increase; and rainbow trout and fish body conditions factors show mixed trends. Numbers of pollutant sensitive EPT invertebrate species decrease in total numbers, while the percentage of these sensitive invertebrates show various trends.

- Most of the negative trends for these factors (except for pollution sensitive EPT invertebrate taxa) appears to occur between June Bug Campground and upstream of Hansen Creek (downstream of Elephant Rock Campground); brown trout populations appear to strengthen through this reach.

- Between Elephant Rock Campground and downstream of Hansen Creek, density and biomass of trout decrease markedly, as do invertebrate densities and diversities. For example, a single rainbow trout was the only fish collected at the downstream of Hansen Creek in September 2000. Numbers of EPT invertebrates potentially sensitive to pollutants, and total invertebrate numbers show trends of improving conditions downstream in the two most recent years of data, and trends of impact in the earlier years.

- At the next downstream site (Goathill Campground), which is downstream of the Molycorp mill, there tends to be increases in trout numbers but decreased in trout biomass. Conditions represented by the invertebrate indicators show a trend of declining conditions between these sites.

- Minimum trout numbers and biomasses and minimum invertebrate densities across all sampling sites regularly occurred at the site upstream of the Questa Ranger Station. Interestingly, this site also generally held the greatest percentage of potentially pollutant sensitive invertebrate species observed in the Red River. In general, potentially sensitive invertebrate taxa occurred on a regular basis at all sampling sites.

- At the site upstream of the hatchery, trout numbers and biomasses increased from those reported upstream. Significant populations of rainbow trout and brown trout occurred in these sampled populations. At this site the condition of the macroinvertebrate community indicated a trend of general improvement from conditions found at the Questa site.

- At the most downstream sampling site, the numbers of rainbow trout markedly decreased, while brown trout populations markedly increased. Also downstream of the hatchery there appears to be, for most years, a slight trend of deterioration in benthic macroinvertebrate populations, especially for the pollution sensitive EPT taxa. This may be related to nutrient and organic loadings to the river accompanying discharges of hatchery waters.

- Body condition for trout tends to be best for rainbow trout in the Red River watershed and poorest for brook trout; however, because different species have different body shapes and they tend to select for habitats having different natural characteristics, direct comparisons between condition factors for different species is often inappropriate (Anderson and Gutreuter, 1983). Overall, condition factors for brown trout, the most widely distributed fish species in the Red River system, was poorest at the tributary sites; along the mainstem of the Red River, minimum condition factors occurred at the site upstream of the Questa Ranger Station.

Tables D-1 and D-2 present information on the stocking by NMGF of the Red River (NMGF, 2001). This information indicates a long history of fish stocking the Red River, with often approximately 30,000 to 40,000 catchable trout planted by NMGF per year, with proportionally more of these fish planted in the upper Red River. In addition, the Town of Red River typically stocks approximately 600 to 800 catchable rainbow trout per week between Memorial Day and Labor Day from the headwaters downstream of the Town of Red River. Instream effects on the dynamics of fish and aquatic invertebrate populations of the Red River from these introductions have not been assessed, but are likely significant.

Table D-3 presents estimates of fishing pressure along the Red River (NMGF, 2001). Estimates of recent fish pressure indicate that greater than 80,000 angler days occur in the Red River, with about 60 percent of that effort occurring in the upper reach of the river. As with fish stocking, the effects of this pressure on the fish and aquatic invertebrate populations have not been quantified, but are likely significant.

Water and Sediment Toxicity

Potential water quality impacts include:

- Direct aluminum toxicity (concentration-based standard [MCL])
- Food base (microinvertebrates) habitat destruction (development of a site-specific biological criterion)

Acute levels of 750 μg/L, or chronic levels of 87 μg/L, high chronic levels of dissolved aluminum are toxic to fish, benthic invertebrates, and some single-celled plants. Chronic dissolved aluminum concentrations from 100 to 300 μg/L increases mortality, and retards growth, gonadal development, and egg production of fish.

Aluminum toxicity has been suggested to be a potentially contributing factor causing adverse effects to aquatic life in the Red River. Its bioavailability and toxicity to aquatic life are highly dependent on water quality, especially pH and dissolved organics. The pH of the water affects both the potential aluminum toxicity and the aluminum species present; dissolved concentrations of aluminum increase as pH decreases below 6.0 (Burrows, 1977; Cronan and Schofield, 1979). However, all of the Red River samples collected by NMED in 1999 and 2000 had pH values at or above 6.5. But local, identifiable inputs (seeps) may have pH of 1 to 4.

In acidic waters, such at those draining the scar areas in the Red River watershed, the most toxic form of aluminum is dissolved inorganic monomeric species such as Al^{3+} and ionic AlOH complexes (Baker, 1983). Chemical ligands that complex with aluminum (e.g. F^- and SO_4^{2-}) generally tend to reduce their bioavailability and toxicity. The most common aluminum complexes in acidic waters are aluminum fluoride and organic aluminum compounds, which can comprise a majority of the total aluminum present (Driscoll et al., 1987). One laboratory assessment of the interactions of four constituents on toxicity to brook trout in acidic waters found that aluminum toxicity has the greatest influence, fluoride concentrations had the least influence, and pH and dissolved organic compounds had intermediate influences on toxicity (Parkhurst et al., 1990). Additionally, both acid and aluminum toxicity are affected by temperature (Gunn, 1986), a factor that also influences rates of most chemical and biological processes. That is, increased temperature is often associated with increased mortality rates for organisms exposed to toxicants, since uptake rates increase as metabolic rates increase.

In more basic waters, including the near neutral-pH waters flowing most of the year through the Red River, precipitated forms of aluminum also can cause mortality of fish (e.g., Muniz and Leivestad, 1980). The toxic action of aluminum precipitates leading to mortality of fish appears most commonly to be the combined effects of (1) osmoregulatory stress due to impaired ion exchange adversely affecting the balance of internal body ions and (2) respiratory stress. Both symptoms are caused by gill clogging, especially due to aluminum precipitation in the relatively more alkaline waters around gills, and tissue damage to the gills caused by chemical-induced gill irritation (e.g., Tietge et al., 1988; Playle and Wood, 1990).

Toxicity testing conducted on samples of Red River water and sediment prior to the October 2000 survey showed little or no toxicity. However, samples tested from the October 2000 survey showed that both water and sediment eluates produced significant adverse effects on egg production by Ceriodaphnia dubia (C. dubia; a small, lake-living water flea) at most of the assessed sites (Table D-4). Also, sediment eluates from samples collected at sites near Zwergle Dam and downstream of Capulin Creek had significantly lower C. dubia survival, and sediment eluate from Junebug Campground had significantly lower the survival of young fathead minnows (Table D4).

The flows for the last several years in the river might have something to do with these toxicity results. The average daily flow at the Questa Gage (near ranger station) during October 1999 was 23.3 cubic feet per second (cfs) and the annual yield was 37,810 acre-feet, while in October 2000, the average daily flow was only 14 cfs and the annual yield was only 14,480 acre-feet, the lowest annual yield on record since 1981. The average annual yield for the last 50 years is 30,927 acre-feet and the average daily flow should be around 22 cfs in October. The fact that 2000 was such a dry year may help to explain the additional toxicity readings

Sediment Embeddedness

The combination of cemented river substrate (potentially resulting in impacted benthic habitat), increased acidity, and elevated concentrations of dissolved and suspended phase contaminant loads undoubtedly has cumulatively impacted the aquatic habitat of the middle reach of Red River. NMED (2000) has established protocols for assessing stream bottom deposits. The procedure involves establishing proper reference sites for site comparisons to help establish best attainable conditions. Assessments involve a combination of physical assessments (i.e., pebble count or embeddedness methods) and macroinvertebrate assessments, with the assessment of results computed as percentages of conditions found at the reference sites. These procedures are included as part of the monitoring program described in the body of this TMDL.

Chadwick (2001) assessed annual variability from 1999 to 2000 in sediment characteristics at the twelve study sites in the Red River watershed. In general percent of surface fines (<2 mm) were greatest at the sites in September 1999, minimum during April 2000 and intermediated in September 2000. These studies also included assessments of the sediment concentrations for aluminum, copper, lead, and zinc at these sites at these same times. Except for aluminum concentrations, sediment concentrations at the sites were relatively similar at each site between the sampling times. Concentrations of aluminum upstream of the Town of Red River were extremely variable, varying by approximately 300 to 400 percent and by about 4,000 to

5,000 mg/kg. Minimum sediment aluminum concentration occurred at the Junebug Campground and the upstream of Hansen Creek sites. Concentrations downstream of Hansen Creek to downstream of the hatchery display a trend of slight increase. Concentrations in sediment from Columbine Creek and Cabresto Creek generally exceeded the concentrations found in sediment from these Red River sites.

Concentrations of copper and lead tended the have concentration maximums at the site downstream of Hansen Creek and to have relatively stable or slightly declining trends downstream. Zinc tended to have continually increasing trends from the sites most upstream to downstream of the hatchery. Chadwick (2001) suggested that these variations might be related to stream flow patterns. That study also concluded that sediment concentrations for copper, lead, and zinc exceeded sediment-screening criteria for lowest toxic effect levels. Also, they suggested that the sediment aluminum concentrations were within the range of baseline conditions for the western United States. As indicated in the following discussion section, additional assessments of these potentially toxic relationships are appropriate.

Discussion

The United States Fish and Wildlife Service (USFWS) (2001) submitted a memo to NMED reporting their reevaluation of data reported by Chadwick (2001). Perhaps because of this analysis focused only on a single year of data from the multiyear monitoring and assessment study, the USFWS memo unfortunately suggests several incorrect and potentially misleading relationships. Without correction, restoration efforts along the Red River watershed could inappropriately focus on water quality issues not potentially producing the maximum or even significant benefits to aquatic life. (Appropriate remediation approaches include those recommended in this TMDL.) Beyond these deficiencies, the USFWS memo provides useful considerations regarding possible sediment effects, especially related to potential toxicity effects for metals that are outside the scope of this TMDL. These relationships also may be important for future water quality assessments and restoration efforts in this watershed. The following discussion examines these issues in relationship to the data described above.

The second paragraph of this USFWS letter includes the assertion that there exists, between the town of Red River and Hansen Creek, "relatively steady biomass [1] concurrent with a decrease in density [2] [that] indicates a shift from smaller fish (e.g., brook trout, other native trout [3]) to large fish (e.g., stocked rainbow) [4]. There is a slight decrease in biomass at the June Bug Campground [5], which may be related to a switch in competitive advantage between brown trout (which prefer bigger, slightly warmer waters) versus previously abundant brook trout (which prefer smaller, cooler headwaters) [6]. But brook trout and brown trout mean weight (biomass) and condition factor (ratio of fish weight to length [7]) actually increases at the June Bug site (bigger fatter fish compared to sites further upstream) [8]. Thus, adverse effects to the fish community due to natural metal loading above Molycorp mine appear to be less severe once biomass and species distribution are considered [9]." [Numbers included in brackets, above, refer to the enumerated discussion presented below.]

[1] In the Fall-2000 samples described here, rather than stable biomasses, there was about a 5-fold decrease in biomass from the site upstream of Zwergle Dam to Junebug Campground, then about 3-fold increase downstream at the site above of Hansen Creek (Figure D-9). Samples in other years also show rather unstable populations among these sites (Figure D-9).

[2] Rather than decreasing densities, samples from 1997 through 2000 show various trends of increase and decrease for densities among these sites for both total fish and non-RBT trout (Figures D-1 and D-7).

[3] To clarify, cutthroat trout is the only native trout in the Red River. Brook, brown, and rainbow trout have all been introduced. Perhaps what is intended here is to note that it appears, in additional to cutthroat trout, brook, brown, and perhaps rainbow trout sustain small "wild populations" in the river through natural reproduction, these three trout taxa have not been stocked in recent years; therefore their persistence in the Red River is likely a result of natural reproduction.

[4] In fact, sample results indicate that brook trout occur upstream of the Town of Red River, but population sizes here are generally very small (Figure D-2). In the upper reaches of the Red River, maximum numbers for sampled rainbow trout populations occur at either of the two sites nearest the town (Figure D-5). This is to be expected since in additional rainbow trout stockings by NMGF, the Town of Red River stocks approximately 600 to 800 trout per week during the tourist season. Wild (i.e., naturally reproducing) brown trout are the most abundant trout by numbers and biomass at the site upstream of Hansen Creek (Figures D-3 through D-6 and Figures D-9 through D-13).

[5] Rather than a biomass decrease, samples from 1997 though 2000 indicate various patterns of fish biomass increase and decrease for the three upper Red River sites (Figure D-8). However, non-RBT trout biomass is regularly greatest at the site upstream of Hansen Creek, the lowest of the three sites (Figure D-10). For these three sites, non-RBT trout biomass generally tends to markedly lower at the site near Junebug Creek, the middle of the three sites.

[6] Indeed, increasing water temperature and increasing stream size downstream is a reasonable basis for explaining the shift from brook trout to brown trout in the non-RBT trout population.

[7] More correctly, condition factor (K) is computed by the equation $K = 10^5 \times W/L^3$; where W = weight in grams and L = length in millimeters (e.g., Anderson and Gutreuter, 1983). The Ks are correctly computed in Appendix A of Chadwick (2001; also see Figure D-15), but are incorrectly computed in the USFWS memo, where unrealistically low Ks (approaching 0.1) are presented in Figure 2 of their memo.

[8] In fact, based on the correctly calculated Ks, while "slightly fatter" stocked rainbow trout occurred at the site near Junebug Campground, slightly "slightly skinner" wild brown trout also were collected at that site (Figure D-15). However, examining the range of condition factors found for both of these trout species at the three upstream sites

(Chadwick, 2001) reveals considerable overlap in the values for both species, such that any such trends have doubtful statistical or, more importantly, biological significance.

[9] In contrast to the USFWS claim, considering the weight of the relationships shown in Figures D-1 through D-15 there is no question that significant sources of impact to the fish populations occur upstream of Molycorp. These impacts are equal to those found downstream. These impacts appear to be most directly related to water quality changes, as discussed in the body of this TMDL. The first impact enters upstream of Junebug Campground and the second impact enters the river between the sites upstream and downstream of Hansen Creek. Indeed, the site downstream of Hansen Creek shows indications of severe water quality impacts, e.g., a single rainbow trout was the only fish collected during the September 2000 sampling (Figure D-5; Chadwick, 2001). Adverse impacts to fish populations are of a similar magnitude at the sites downstream of Hansen Creek and upstream of the Questa Ranger Station (Figures D-1, D-7, D-8, and D-14).

Page 3 of the USFWS letter corrected notes that a diversity of impacts might be impacting fish downstream of Hansen Creek, and effects due water quality are likely one of the more important. They report that rainbow trout are absent "below the Molycorp property…." In fact, as shown in Figure D-2, they are generally rare to absent from Hansen Creek (upstream of Molycorp) through the site upstream of the Questa Ranger Station. The USFWS correctly suggest that various laboratory and field studies indicate that rainbow trout typically show greater sensitivity to metal toxicity than other trout species. This very likely helps to account for their general scarcity from Hansen Creek through the Questa site. Similarly, brown trout tend to have lesser sensitivity to metals in laboratory exposures. Additionally, the behavioral tendency of brown trout to seek protective cover, more so than other trout species, also likely contributes to their reduced stress and susceptibility to toxic impact in the wild, including this reach of the Red River. The condition factors for brown trout were lowest at the Questa Ranger Station site, indicating likely potentially the greatest stressful conditions of all the Red River sites. It is also interesting to note, however, that lowest condition factors for brown trout occurred at the Columbine and Cabresto creek sites (Figure D-15). This tends to suggest that stresses affecting brown trout at the Questa Ranger Station site were not as severe as those affecting populations occurring at the two tributary sites, both apparently unaffected by metal pollutants.

The statement by the USFWS on page 3 of their letter that, "it is possible that the Red River is markedly 'biologically impoverished' or 'devoid of aquatic life' during" some wet-weather events has little support in the available data relative to any studied reach of the river. In fact, considering the rather diverse population of benthic macroinvertebrates recorded over the past several years (cf., Figures D-16 to D-20), such occurrences on a wide-scale appear to be improbable. Such condition might possibly occur briefly over localized reaches, especially the reaches downstream of Hansen Creek and through the Questa Ranger Station.

The USFWS letter on page 3 emphases the need for establishing self-sustaining populations and ecosystems, particularly in relationship the closure of the Molycorp site. But this letter does not define how such conditions would be defined. It is important to recognize that, at least to a limited extent, self-sustaining populations and a sustainable ecosystem appear to exist throughout most, if not all of the Red River. That is, reasonably diverse assemblages of both tolerant and sensitive benthic macroinvertebrates occur throughout the system and naturally reproducing "wild" populations of brown trout, mixed with other trout species, are found consistently at most of the sites. Procedures are presented in the body of the TMDL through which these populations can continue to be assessed to determine progress attained through the TMDL implementation plan in enhancing these populations throughout the waters of the Red River watershed.

The letter correctly notes on page 4 that the "invertebrate community data are equivocal." Indeed, the benthic communities found at the sampling sites show inconsistent, if not a bewildering set of patterns. As such, various confounding influences are likely affecting the benthic community, including fine sediment, metal toxicity, and physical scouring during snowmelt and storm flows, as suggested in the letter. Of importance, the USFWS letter discusses the potential influence of sediment concentrations of metals (i.e., zinc and copper) that are beyond the scope of this TMDL. They provide a logically suggestion that additional assessment is needed to correctly evaluate these potential toxic effects and supply useful suggestions on how to better accomplish appropriate assessments of potential fine and toxic sediment effects.

In closing their memo, the USFWS stresses the need to address issues in the Red River particularly associated with the closure of the Molycorp site. They unfortunately and inappropriately minimize the importance of addressing loadings from other sources in the watershed, especially those upstream of Molycorp. Extreme caution is required so that the restoration of the Red River watershed is not incorrectly focused only on reaches and activities associated with Molycorp. There is no question that significant past impacts to water quality in the Red River are attributable to Molycorp's operations. But today, there is overwhelming evidence that other sources in the watershed are now producing perhaps equal or greater impacts to water quality and aquatic life in this system. Successful restoration of the Red River watershed to achieve maximum sustainable aquatic populations will require a balanced approach that addresses both natural and manmade sources affecting this river's water quality. This TMDL presents appropriate steps to progress successfully in this restoration.

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Table D-1. NMGF Trout Stocking 1977-2000 for entire reach of the Red River (data given in numbers of fish stocked).

Year	Type of Trout			Total
	Rainbows [1]	Browns [2]	Cutthroat [2]	
1976	169,040	33,300	0	202,340
1977	455,985	0	49,500	505,485
1978	64,387	0	22,305	86,692
1979	57,997	53,222	0	111,219
1980	63,831	0	0	63,831
1981	74,108	0	0	74,108
1982	66,345	0	0	66,345
1983	74,370	5,536	0	79,906
1984	49,601	0	0	49,601
1985	47,708	0	0	47,708
1986	28,798	0	0	28,798
1987	48,422	30,000	0	78,422
1988	49,903	0	0	49,903
1989	40,200	0	0	40,200
1990	40,601	0	0	40,601
1991	43,000	0	0	43,000
1992	43,004	0	0	43,004
1993	42,700	0	0	42,700
1994	XX	XX	XX	XX
1995	XX	XX	XX	XX
1996	XX	XX	XX	XX
1997	XX	XX	XX	XX
1998	31,427	0	0	31,427
1999	38,740	0	0	38,740
2000	41,245	0	0	41,245

XX = missing data

[1] = all rainbow stockings are 9" or greater except in 1984, 1986, and 1987. In 1984, 25,000 were fingerlings; in 1986, 3,000 were fingerlings; and in 1987, 44,000 were fingerlings.

[2] = brown and cutthroat stockings were fingerlings in all years

Table D-2. NMGF Rainbow Trout Stocking Post 1997 of Upper and Lower Reaches of Red River (data given in number of fish)

Year	Upper River	Lower River	Total
1998	21,242	10,185	31,427
1999	31,740	7,000	38,740
2000	34,245	7,000	41,245

Table D-3. NMGF Estimates of Annual Angler Days

License Ye	Upper River	Lower River	Entire River
1975-76			27,041
1976-78			
1978-79			38,785
1981-82			37,965
1982-83			36,995
1983-84			18,093
1984-85			22,347
1985-86			25,581
1986-87			27,111
1988-89			17,348
1990-91			25,396
1991-97			
1997-98	52,806	32,850	85,656
1998-99	45,138	30,785	75,923

Table D-4. Mean toxic response to Red River water and sediment eluate samples in standard toxicity tests using fathead minnow (FHM) and Ceriodaphnia dubia (C. dubia)

NMED Site Number	Site Description	Source	Date Collected	Water - FHM 7-d Embryo Larval Affected %	Water - C. dubia 7-d Survival %	Water - C. dubia 7-d Reproduction (young / female)	Sig. Dif. from Ref.	Sediment Eluate - FHM 7-d Embryo Larval Affects %	Sig. Dif. from Ref.	Sediment Eluate - C. dubia 7-d Survival %	Sig. Dif. from Ref.	Sediment Eluate - C. dubia 7-d Reproduction (young / female)	Sig. Dif. from Ref.
<u>Laboratory Water Reference Samples</u>													
	SWQB	SWQB 2000	Oct 25, 2000	0	100	18.2		3		0		18.1	
	SWQB	SWQB 2000	Oct 26, 2000	0	100	16.3		0		100		16.3	
	Chadwick	Chadwick 2001	Oct 25, 2000	10, 10, 7.5	100, 100, 90	25.8, 26.4, 28.9		7.5, 10, 22.5		100, 90, 100		23.5, 23.8, 19	
<u>Upstream Reference Sample Site</u>													
RR06	Upstream of Zwergle Dam	SWQB 2000	Oct 25, 2000	0	100	**11.8**	**a**	0		**60**	**a**	**8.5**	**a**
		SWQB 2000	Oct 26, 2000	97	100	17.9		0		70		**10.6**	**a**
<u>Downstream Effects Sample Sites</u>													
RR15	At JuneBug Campground	Chadwick 2001	Oct 25, 2000	27.5	100	23.2		**55**	**a**	90		**17.6**	**a**
RR20	Downstrem Hansen Creek confluence	Chadwick 2001	Oct 25, 2000	5	100	**12.1**	**a**	17.5		80		**17.1**	**a**
RR27	At Goat Hill Gulch campground	Chadwick 2001	Oct 25, 2000	15	90	**11.7**	**a**	5		100		**7.3**	**a**
RR29	Downstream Capulin Creek	SWQB 2000	Oct 25, 2000	0	100	**16.6**	**a**	7		**30**	**a**	**4.6**	**a**
			Oct 26, 2000	93	100	15.7		7		90		14.8	
		SWQB 2000											
RR35	Downstream Molycorp outfall 002	SWQB 2000	Oct 25, 2000	3	100	**11.1**	**a**	3		80		**15.1**	**a**
		SWQB 2000	Oct 26, 2000	97	100	16		3		100		17.1	

a Boxed values are significantly different from corresponding reference sample; SWQB had single reference sample for each set of 3 site toxicity analyses; Chadwick had 1 reference sample for each site toxicity analysis.

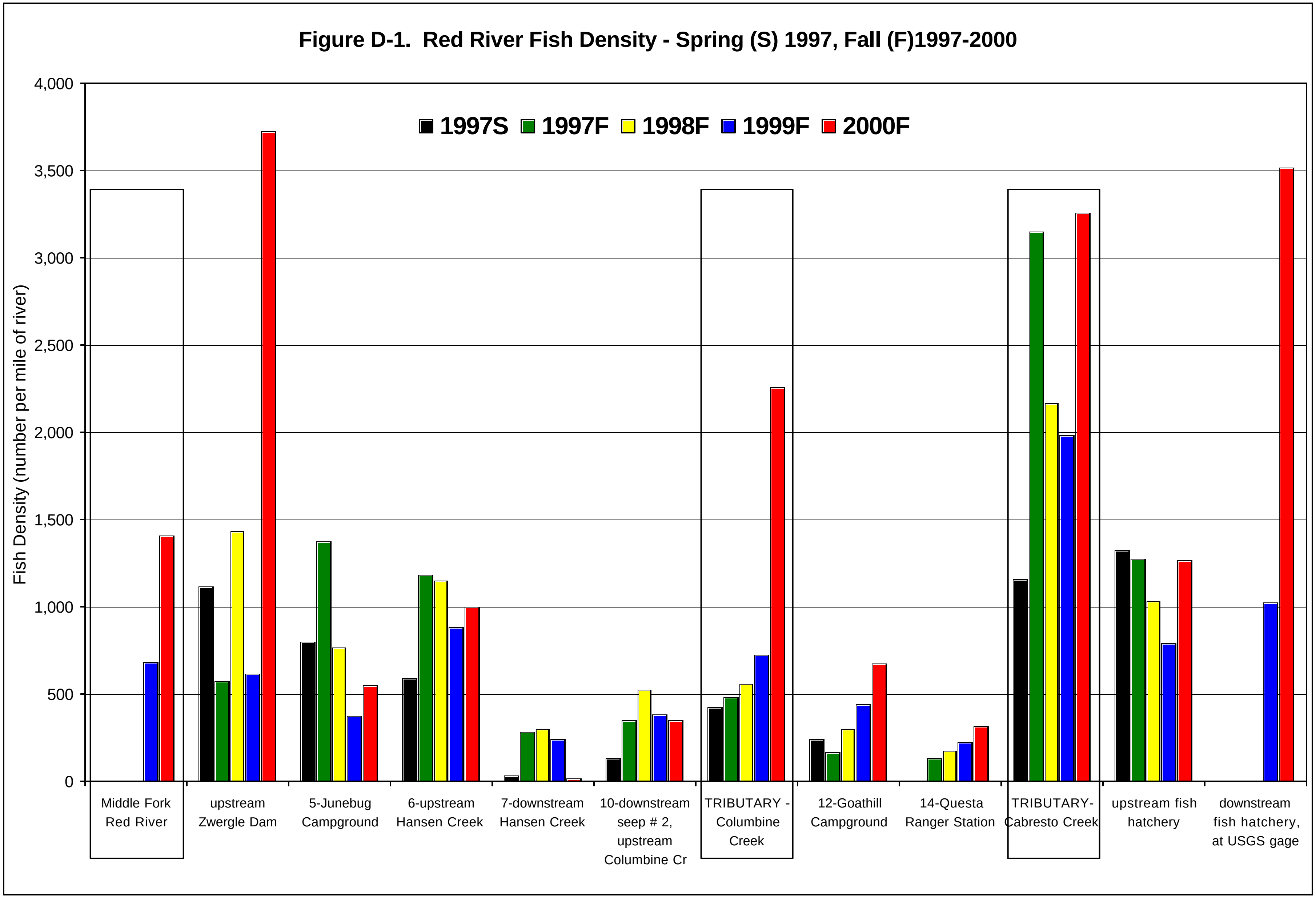


Figure D-1. Red River Fish Density - Spring (S) 1997, Fall (F)1997-2000
1997S 1997F 1998F 1999F 2000F
Fish Density (number per mile of river)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station
TRIBUTARY- Cabresto Creek
upstream fish hatchery
downstream fish hatchery, at USGS gage

Figure D-2. Red River Brook Trout Density - Spring (S) 1997, Fall (F)1997-2000

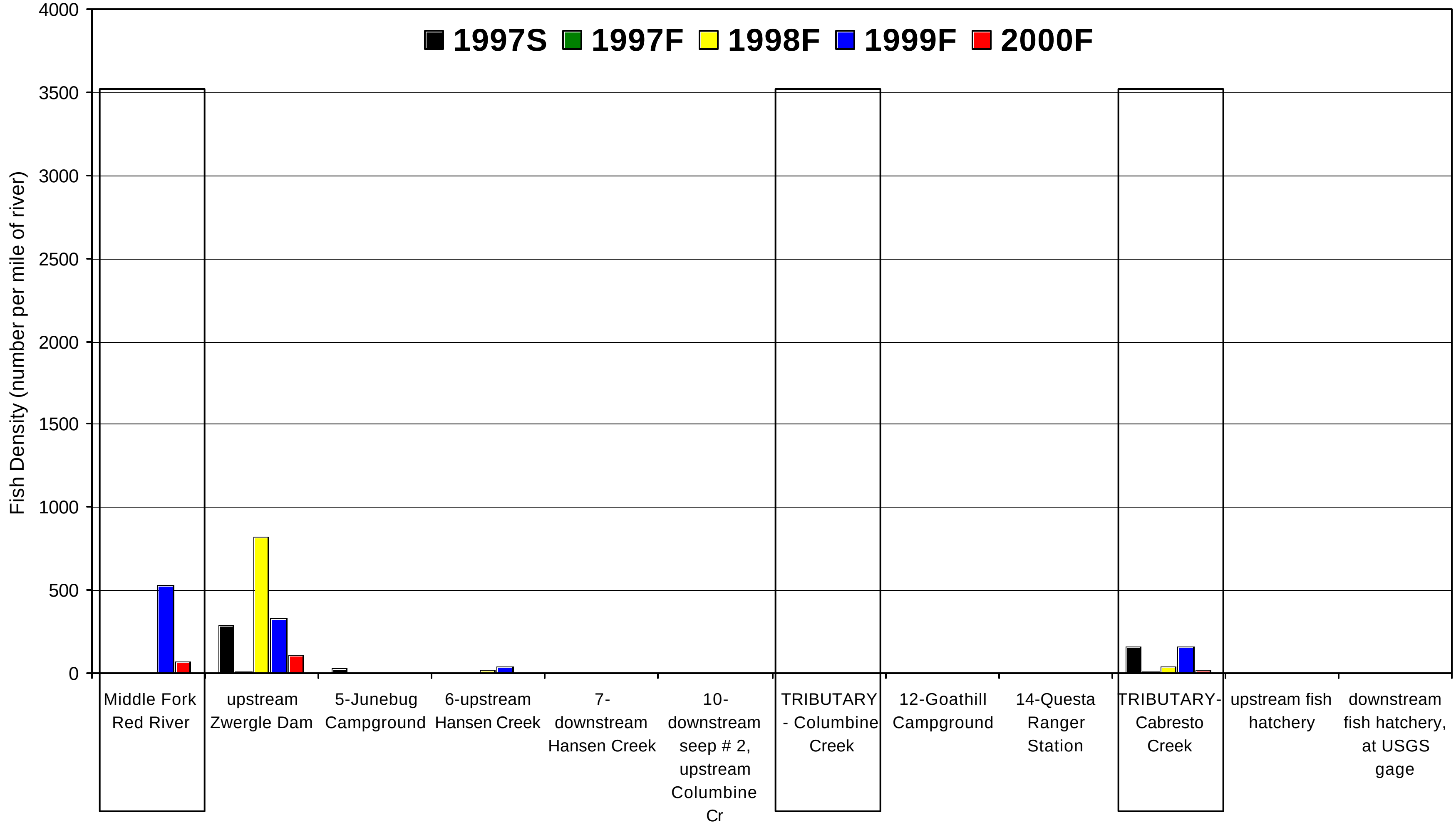
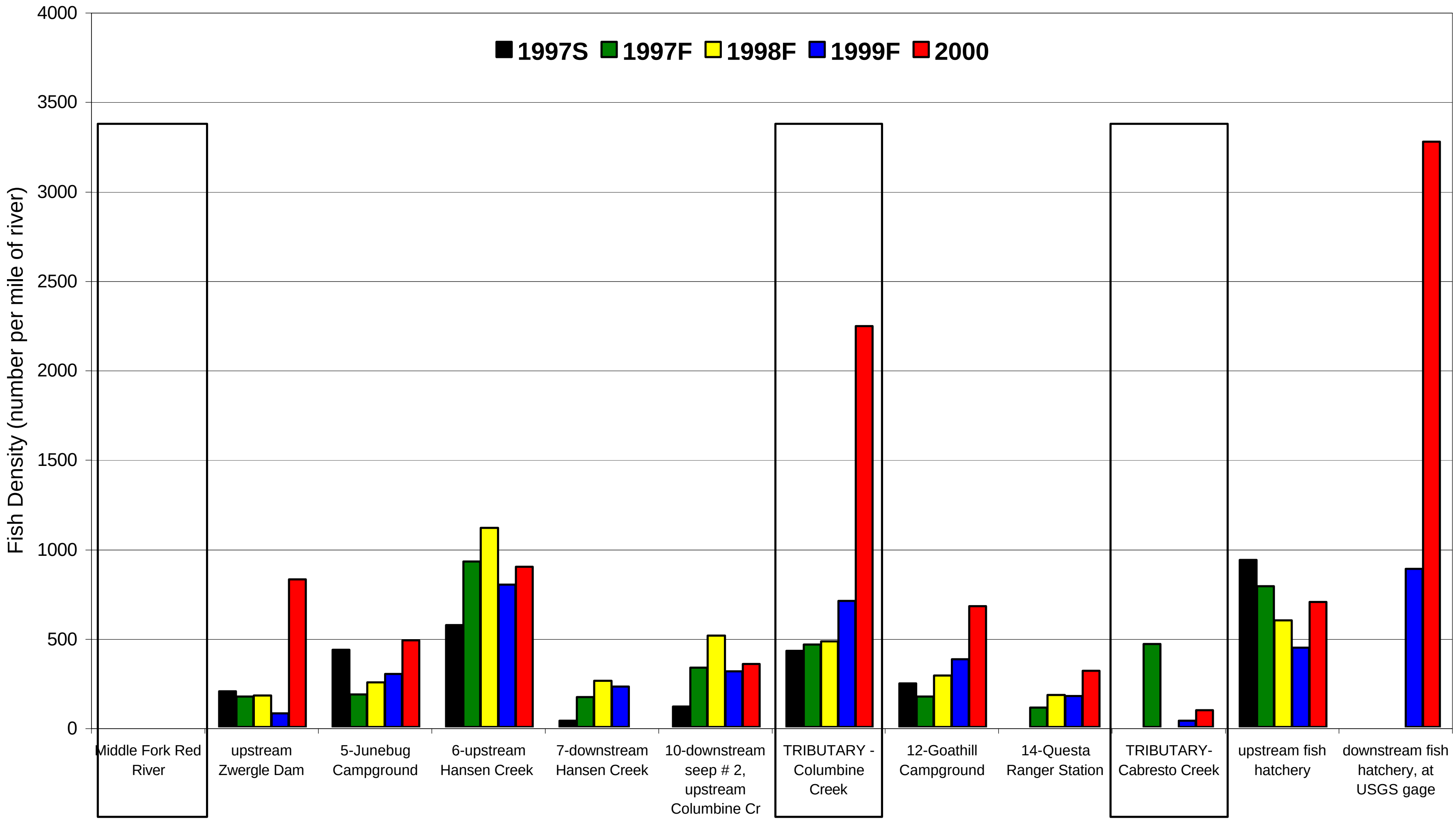


Figure D-3. Red River Brown Trout Density - Spring (S) 1997, Fall (F)1997-2000



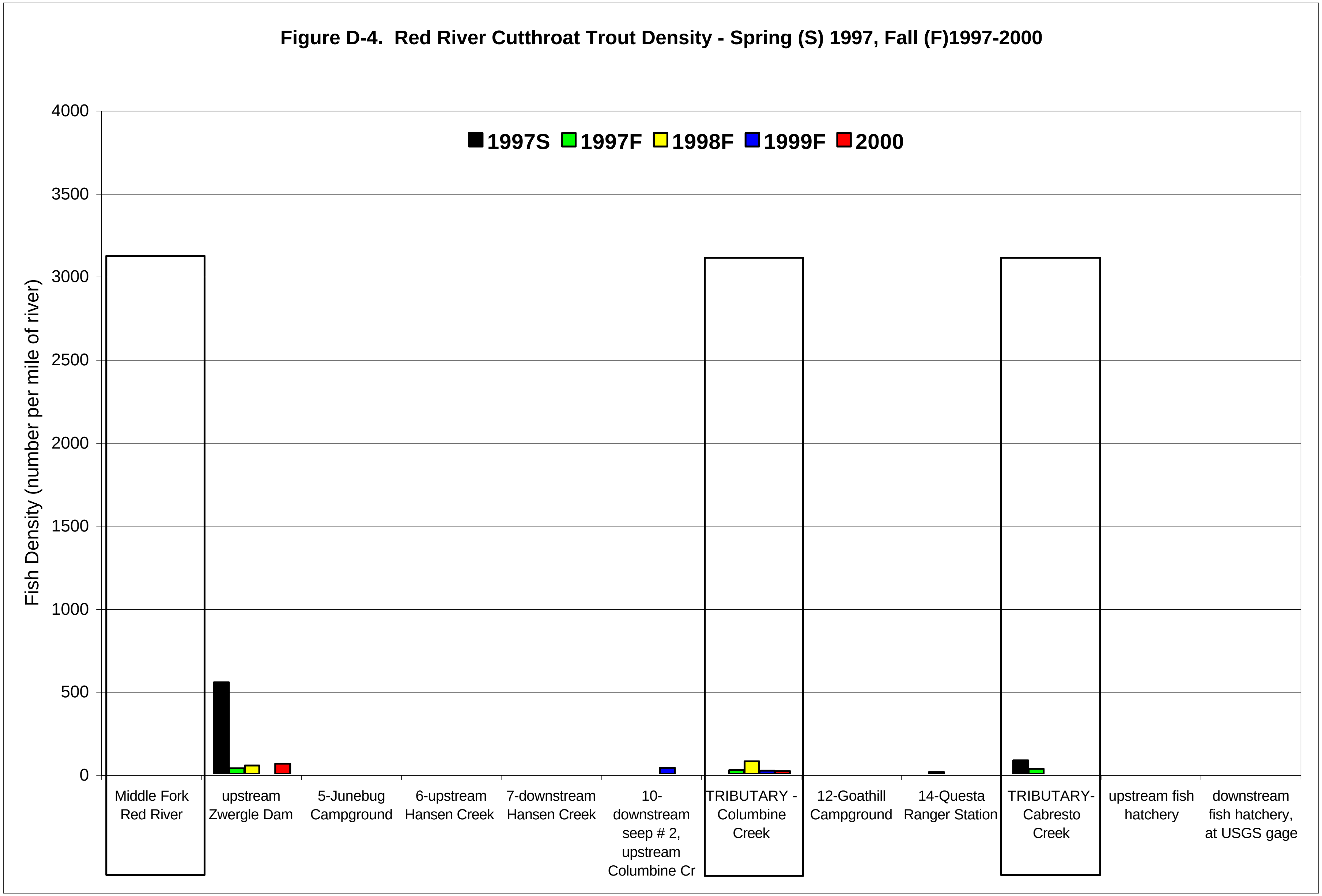


Figure D-4. Red River Cutthroat Trout Density - Spring (S) 1997, Fall (F)1997-2000
1997S
1997F
1998F
1999F
2000
Fish Density (number per mile of river)
4000
3500
3000
2500
2000
1500
1000
500
0
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station
TRIBUTARY- Cabresto Creek
upstream fish hatchery
downstream fish hatchery, at USGS gage

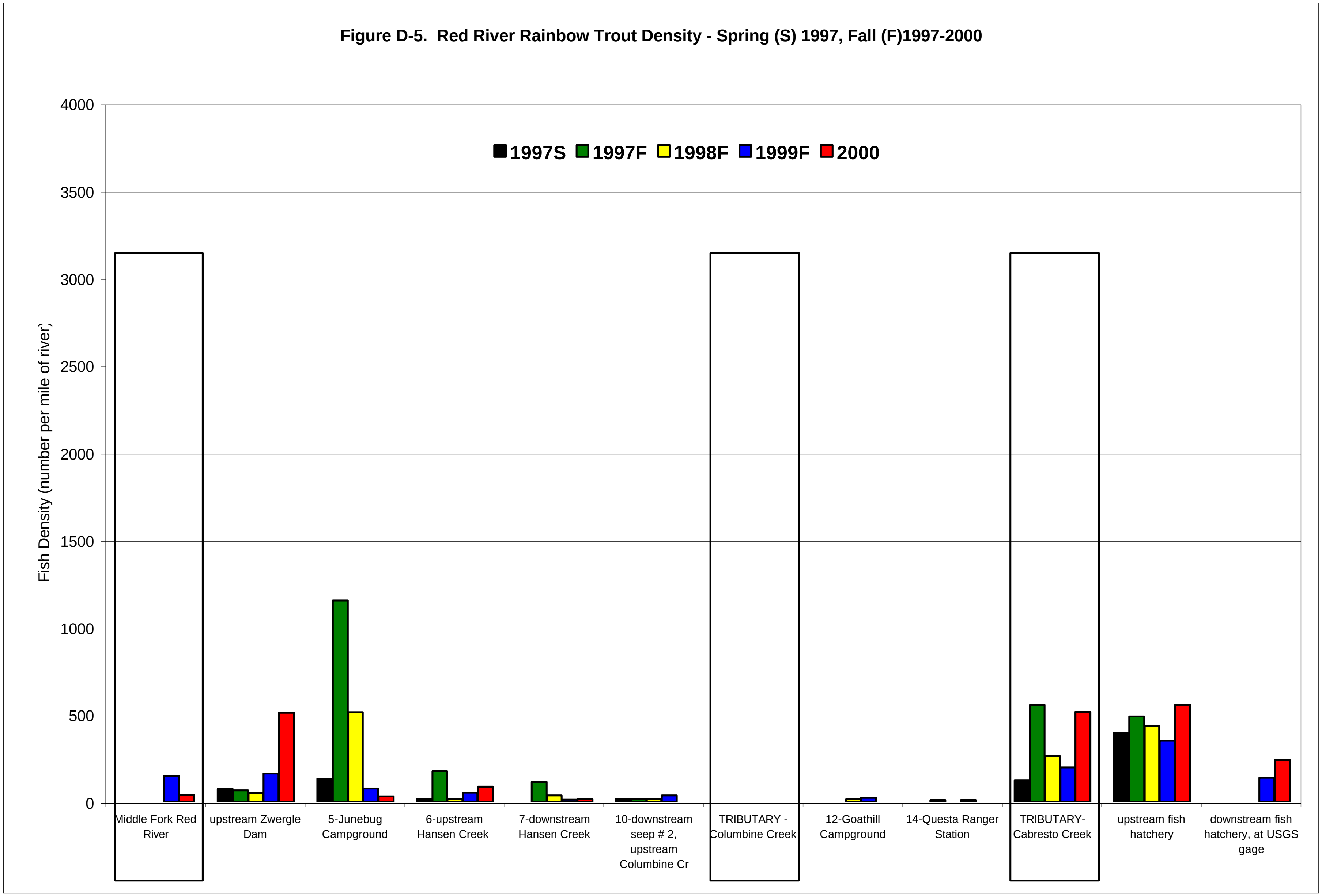
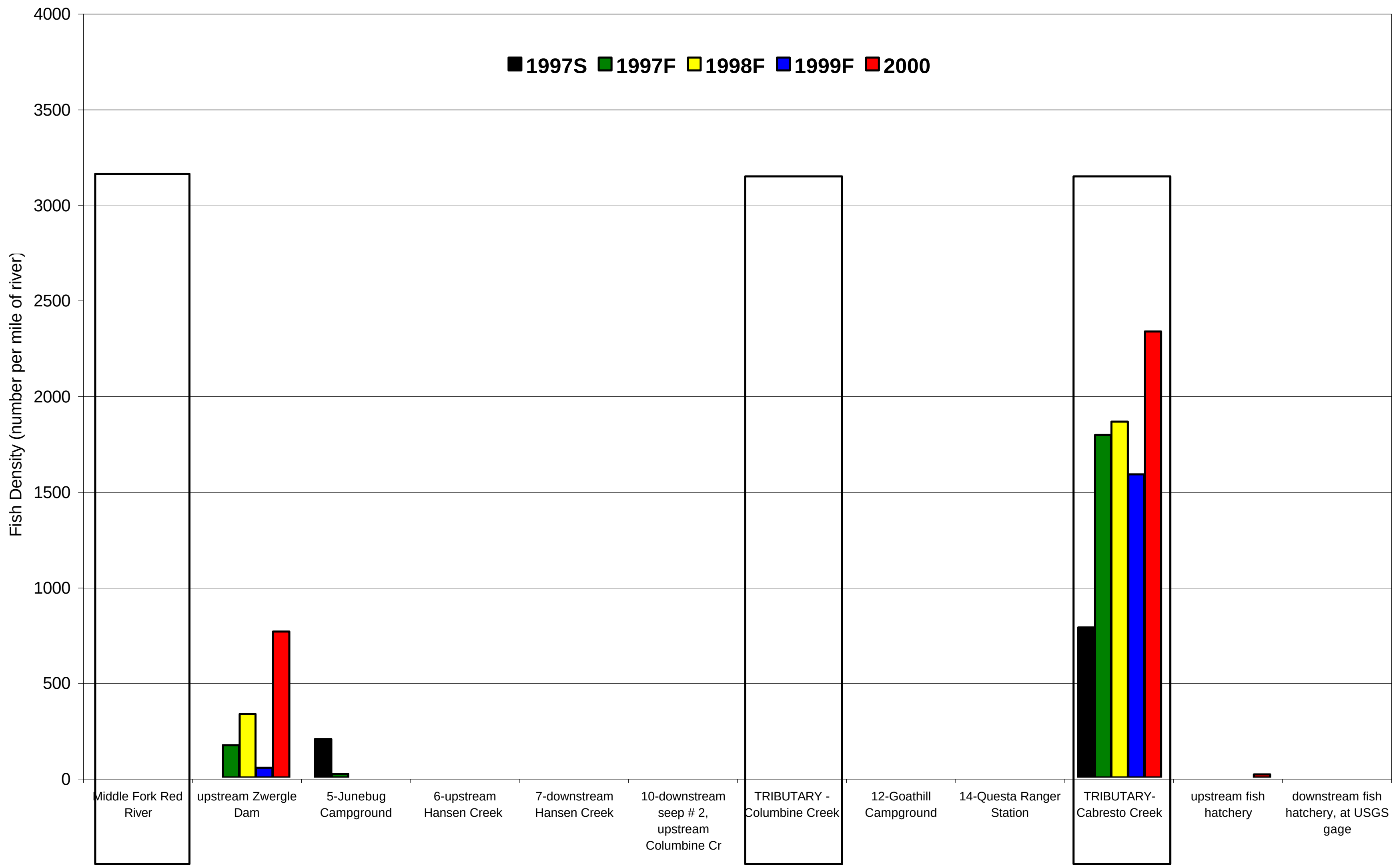


Figure D-5. Red River Rainbow Trout Density - Spring (S) 1997, Fall (F)1997-2000
1997S
1997F
1998F
1999F
2000
Fish Density (number per mile of river)
0
500
1000
1500
2000
2500
3000
3500
4000
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station
TRIBUTARY- Cabresto Creek
upstream fish hatchery
downstream fish hatchery, at USGS gage

Figure D-6. Red River Rainbow/Cutthroat Hybrid Trout Density - Spring (S) 1997, Fall (F)1997-2000



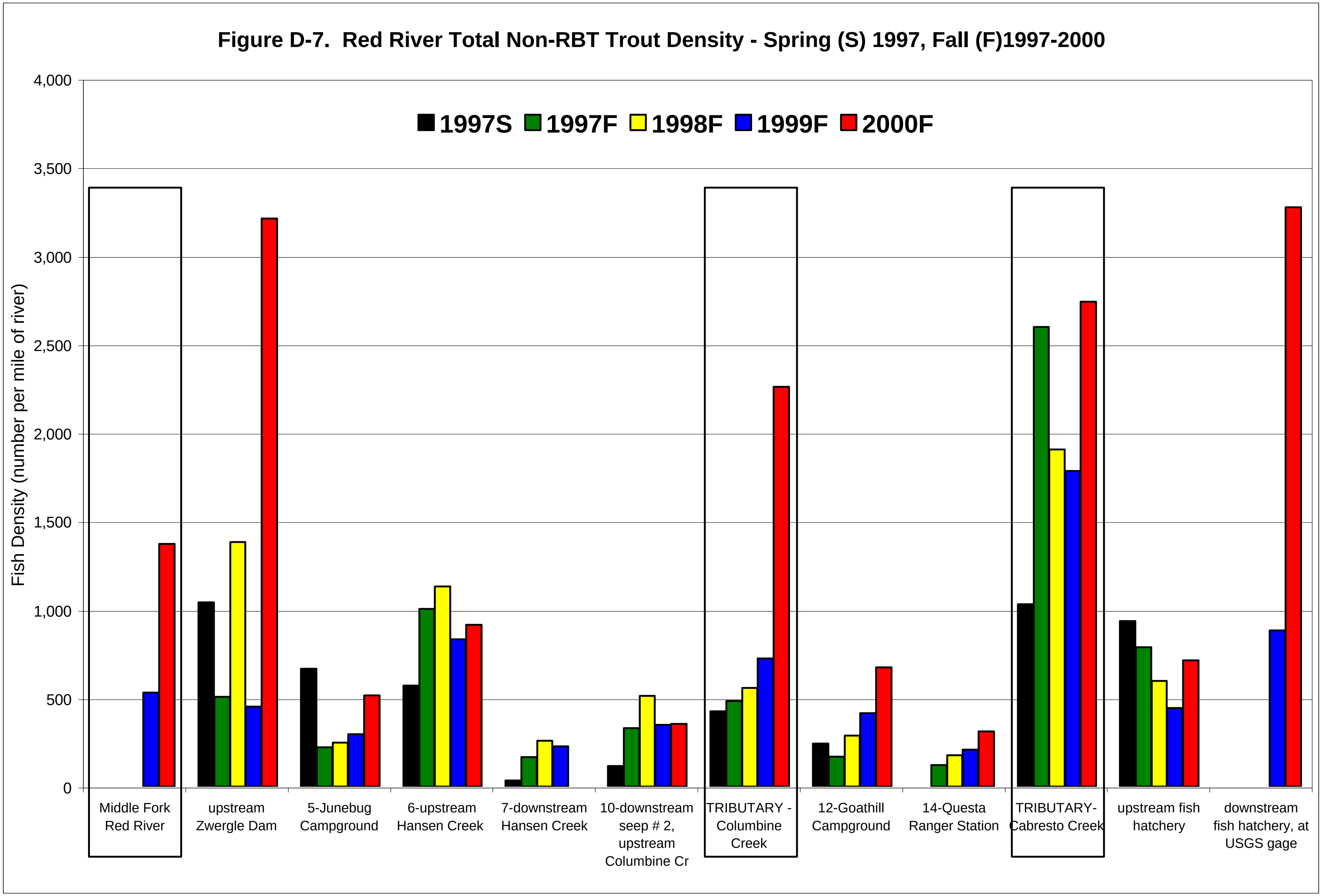


Figure D-7. Red River Total Non-RBT Trout Density - Spring (S) 1997, Fall (F)1997-2000
1997S
1997F
1998F
1999F
2000F
Fish Density (number per mile of river)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station
TRIBUTARY- Cabresto Creek
upstream fish hatchery
downstream fish hatchery, at USGS gage

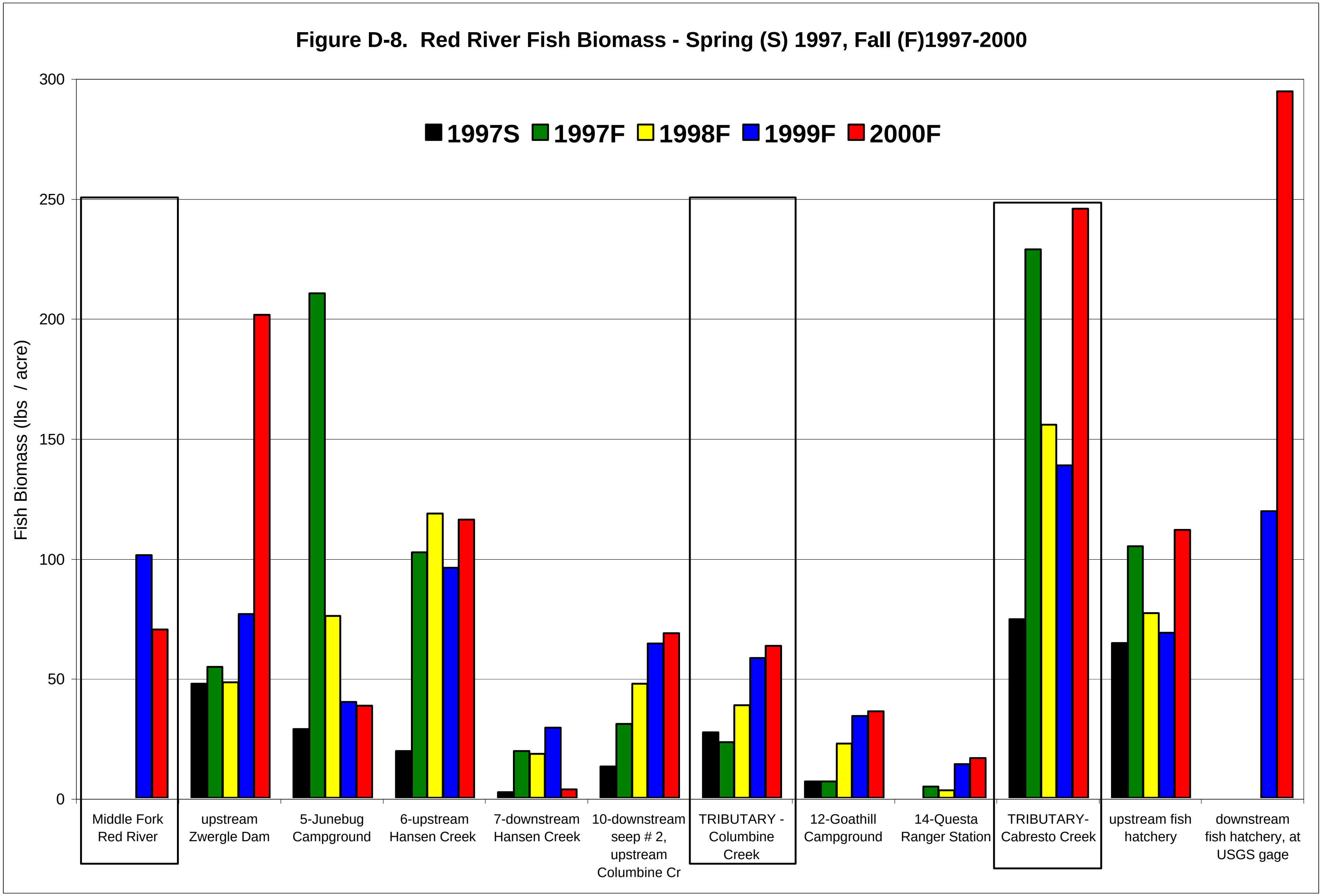


Figure D-8. Red River Fish Biomass - Spring (S) 1997, Fall (F)1997-2000
1997S 1997F 1998F 1999F 2000F
Fish Biomass (lbs / acre)
300
250
200
150
100
50
0
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station
TRIBUTARY- Cabresto Creek
upstream fish hatchery
downstream fish hatchery, at USGS gage

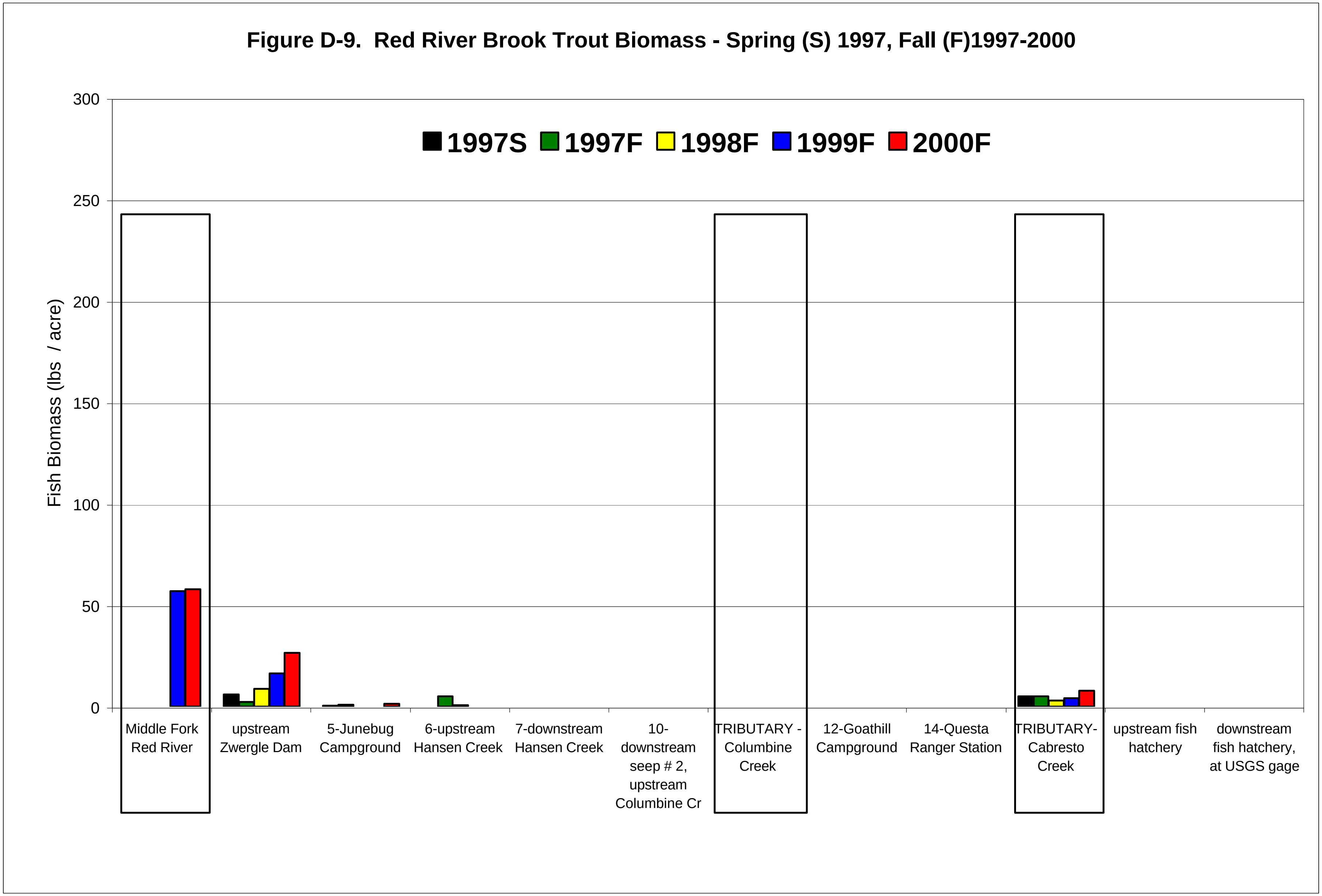


Figure D-9. Red River Brook Trout Biomass - Spring (S) 1997, Fall (F)1997-2000
1997S
1997F
1998F
1999F
2000F
Fish Biomass (lbs / acre)
300
250
200
150
100
50
0
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station
TRIBUTARY- Cabresto Creek
upstream fish hatchery
downstream fish hatchery, at USGS gage

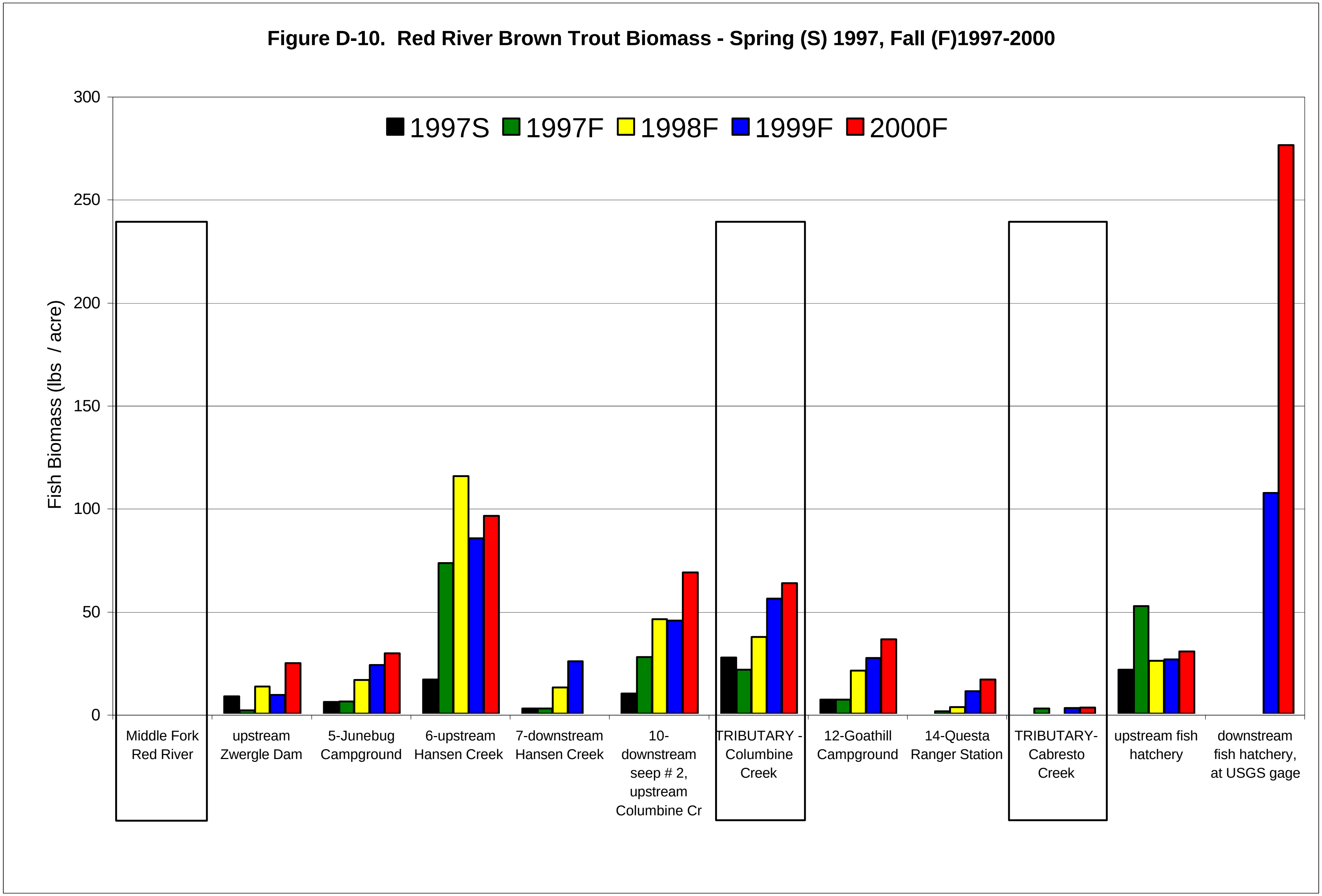


Figure D-10. Red River Brown Trout Biomass - Spring (S) 1997, Fall (F)1997-2000
1997S 1997F 1998F 1999F 2000F
Fish Biomass (lbs / acre)
300
250
200
150
100
50
0
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station
TRIBUTARY-Cabresto Creek
upstream fish hatchery
downstream fish hatchery, at USGS gage

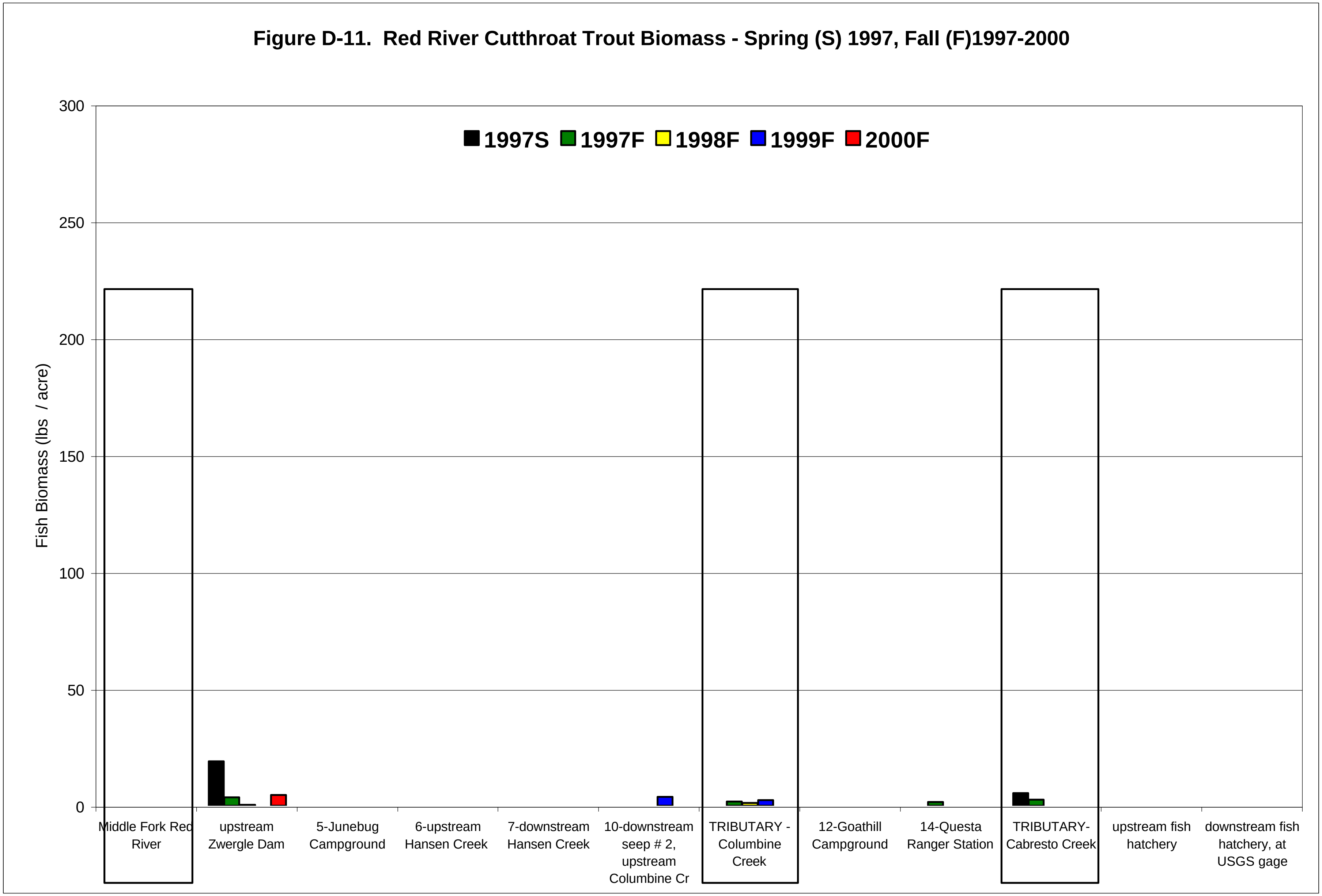


Figure D-11. Red River Cutthroat Trout Biomass - Spring (S) 1997, Fall (F)1997-2000
Fish Biomass (lbs / acre)
0
50
100
150
200
250
300
1997S
1997F
1998F
1999F
2000F
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station
TRIBUTARY- Cabresto Creek
upstream fish hatchery
downstream fish hatchery, at USGS gage

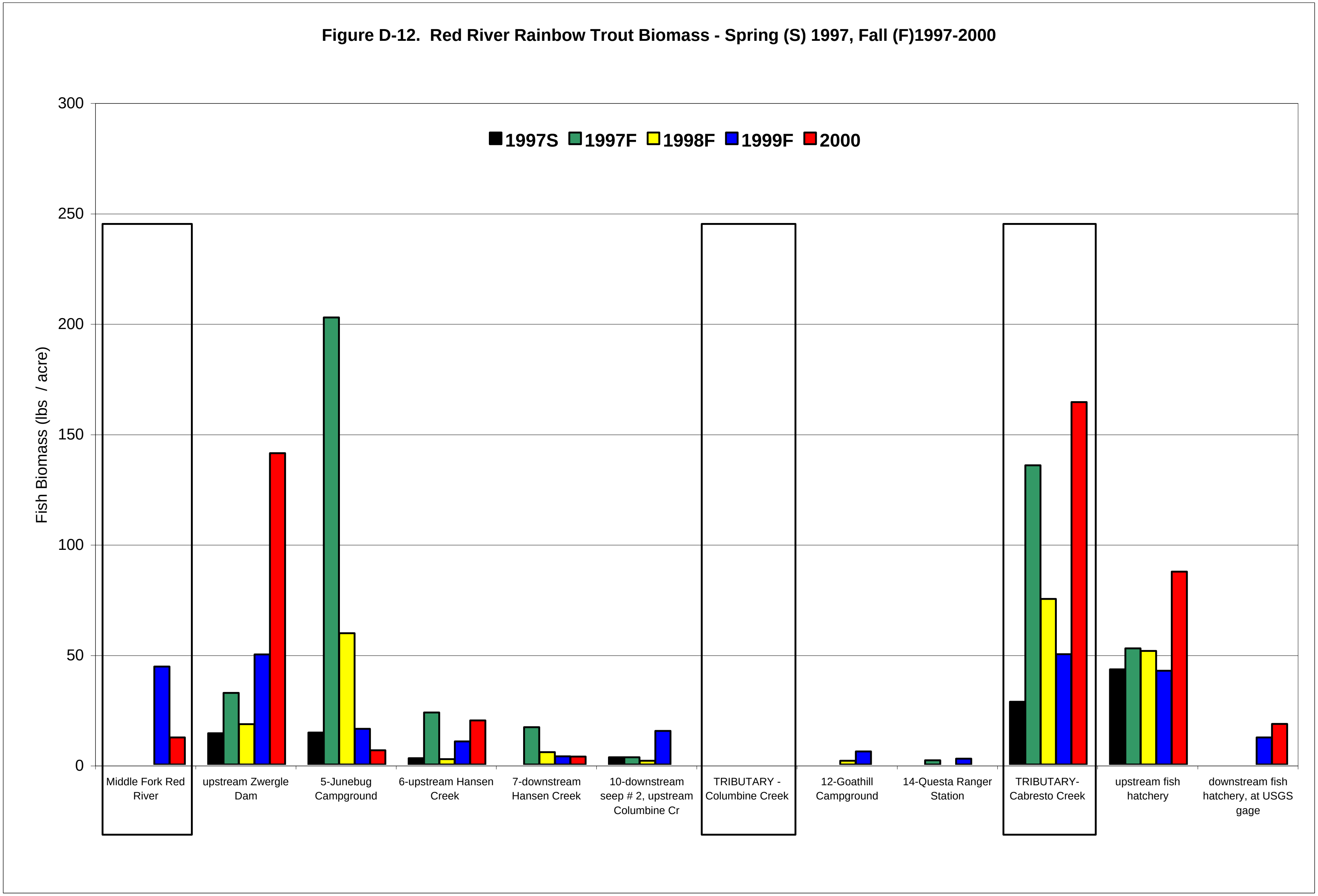
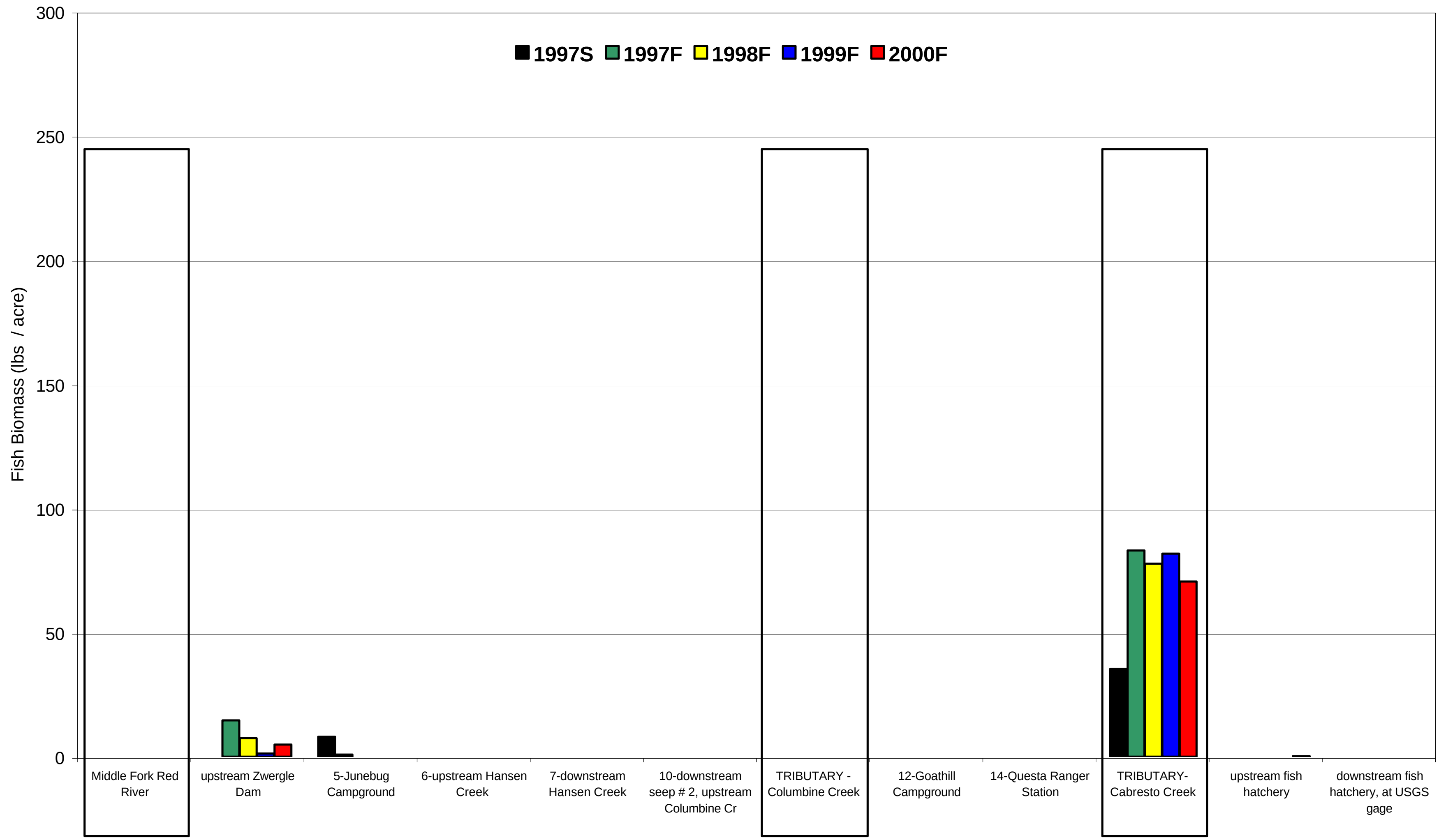


Figure D-12. Red River Rainbow Trout Biomass - Spring (S) 1997, Fall (F)1997-2000
1997S
1997F
1998F
1999F
2000
Fish Biomass (lbs / acre)
300
250
200
150
100
50
0
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station
TRIBUTARY- Cabresto Creek
upstream fish hatchery
downstream fish hatchery, at USGS gage

Figure D-13. Red River Rainbow/Cutthroat Hybrid Trout Biomass - Spring (S) 1997, Fall (F)1997-2000



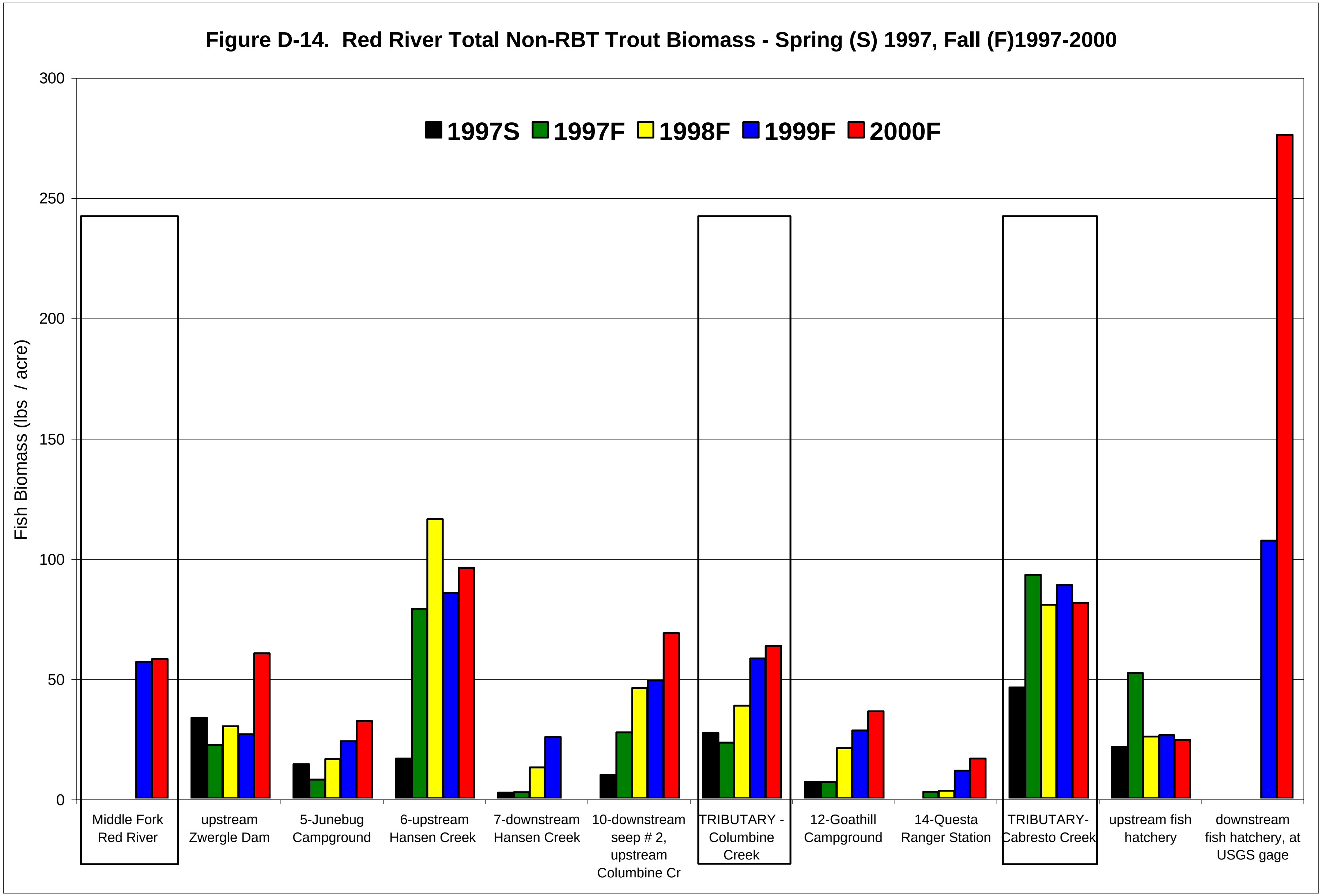


Figure D-14. Red River Total Non-RBT Trout Biomass - Spring (S) 1997, Fall (F)1997-2000
Fish Biomass (lbs / acre)
300
250
200
150
100
50
0
1997S
1997F
1998F
1999F
2000F
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station
TRIBUTARY- Cabresto Creek
upstream fish hatchery
downstream fish hatchery, at USGS gage

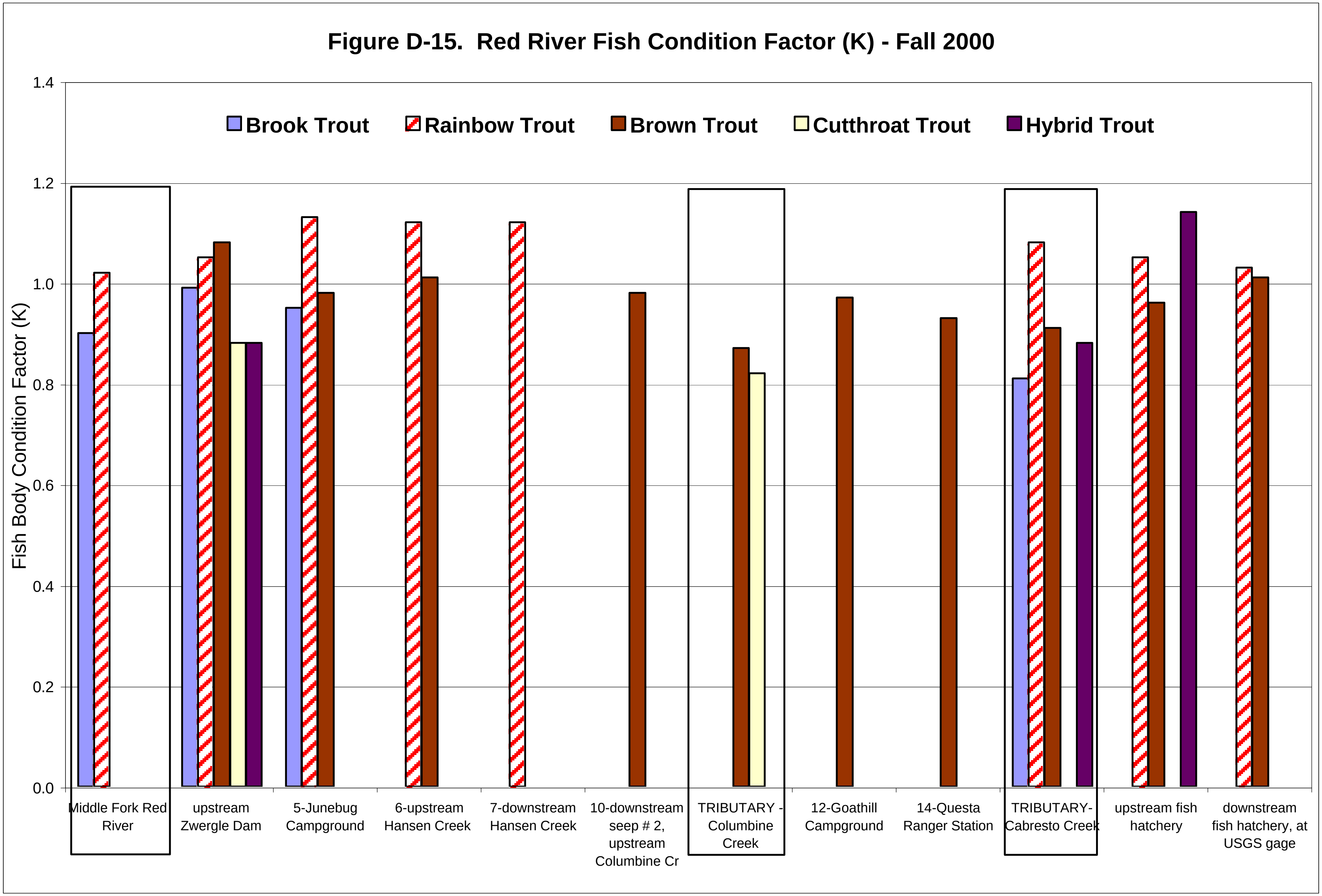


Figure D-15. Red River Fish Condition Factor (K) - Fall 2000
Brook Trout
Rainbow Trout
Brown Trout
Cutthroat Trout
Hybrid Trout
Fish Body Condition Factor (K)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station
TRIBUTARY- Cabresto Creek
upstream fish hatchery
downstream fish hatchery, at USGS gage

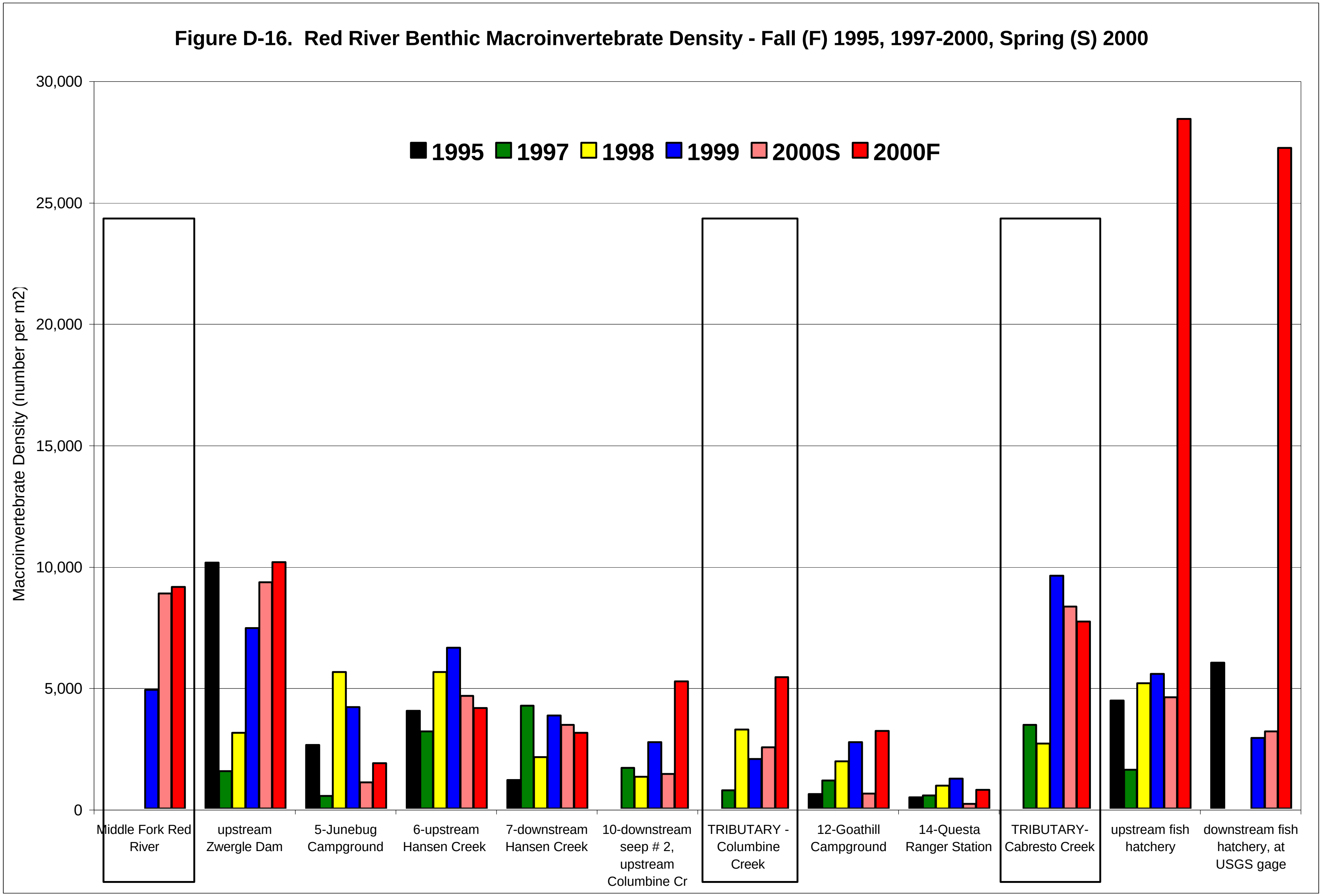


Figure D-16. Red River Benthic Macroinvertebrate Density - Fall (F) 1995, 1997-2000, Spring (S) 2000
Macroinvertebrate Density (number per m2)
30,000
25,000
20,000
15,000
10,000
5,000
0
1995
1997
1998
1999
2000S
2000F
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station
TRIBUTARY- Cabresto Creek
upstream fish hatchery
downstream fish hatchery, at USGS gage

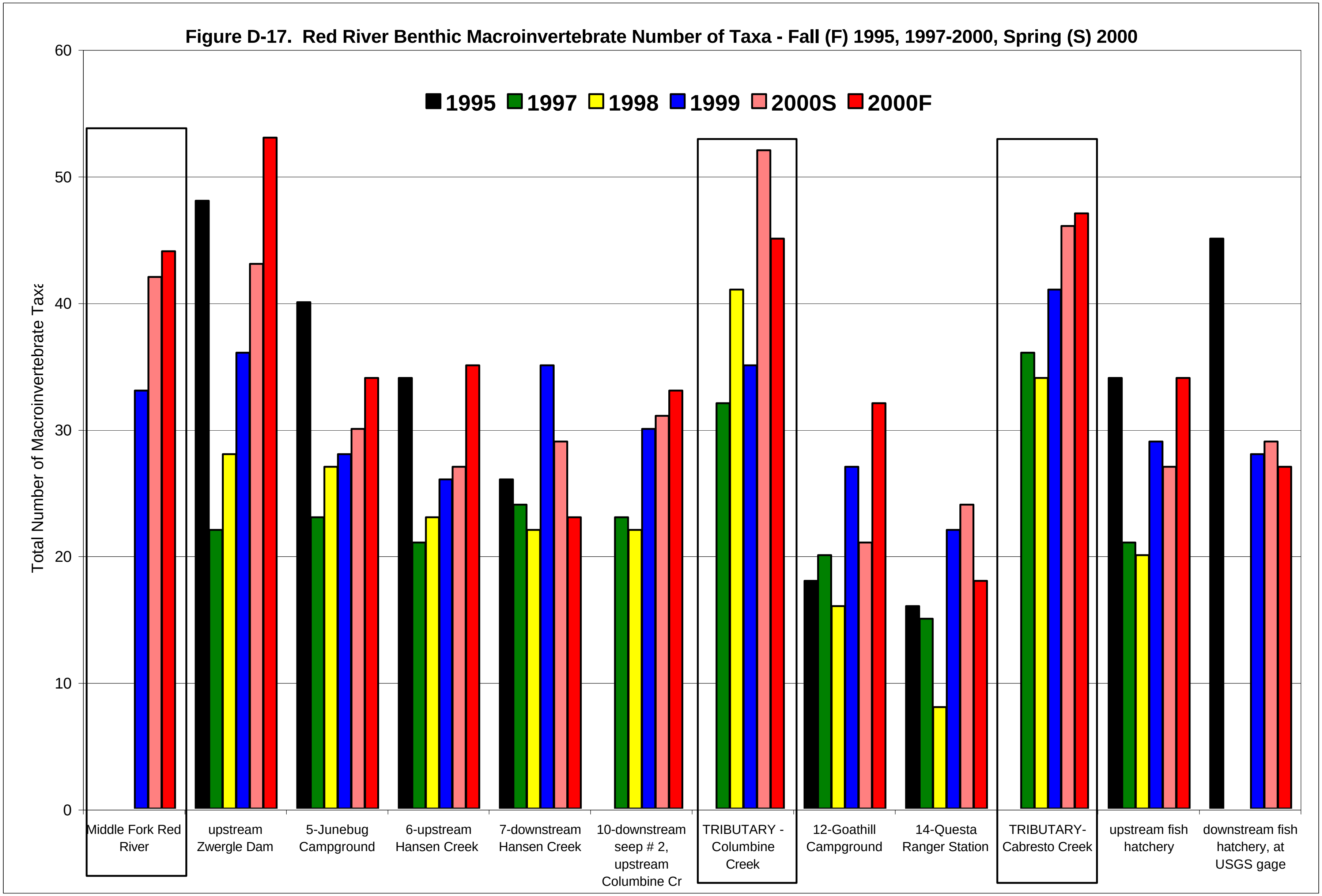


Figure D-17. Red River Benthic Macroinvertebrate Number of Taxa - Fall (F) 1995, 1997-2000, Spring (S) 2000
1995
1997
1998
1999
2000S
2000F
Total Number of Macroinvertebrate Taxa
0
10
20
30
40
50
60
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station
TRIBUTARY- Cabresto Creek
upstream fish hatchery
downstream fish hatchery, at USGS gage

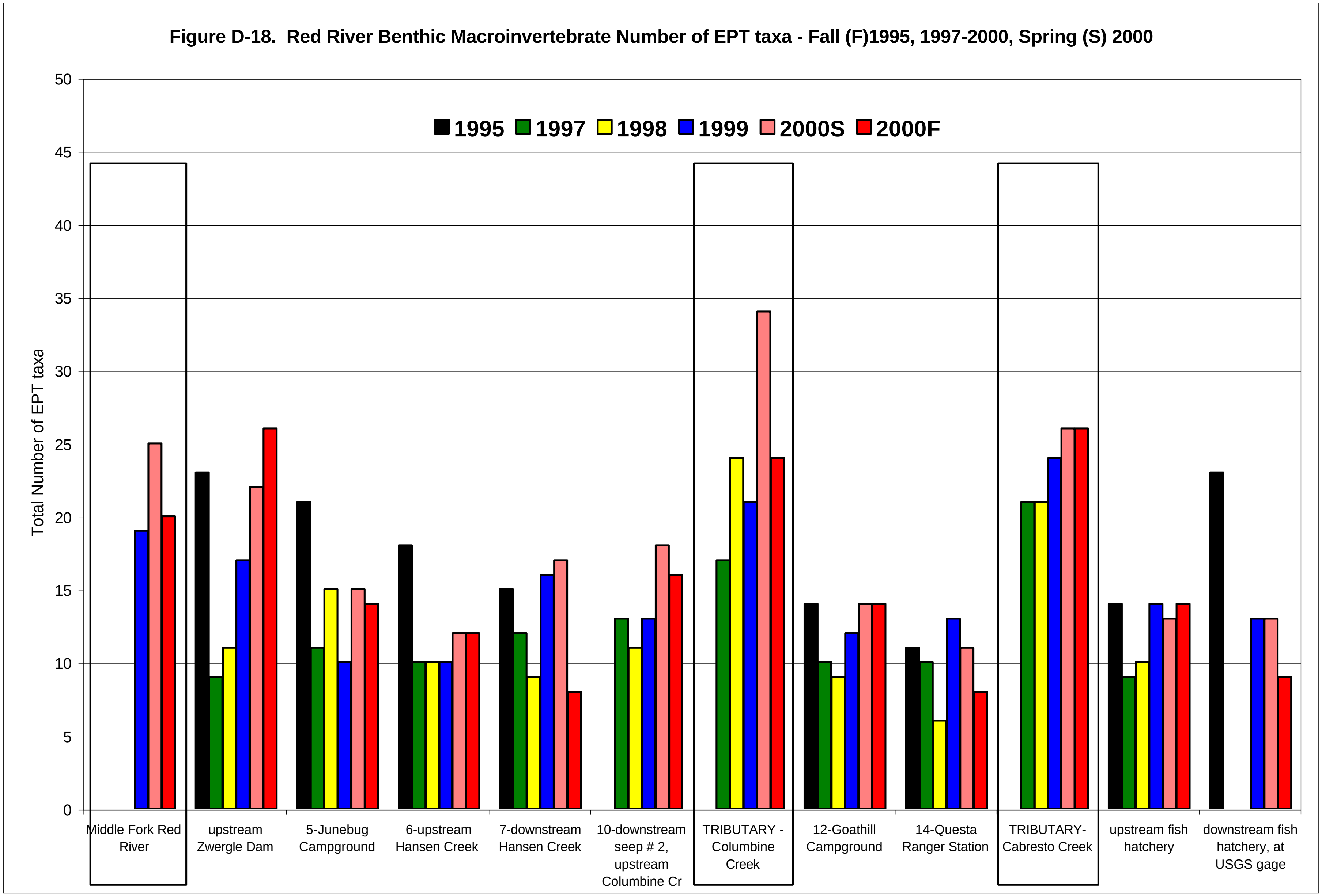


Figure D-18. Red River Benthic Macroinvertebrate Number of EPT taxa - Fall (F)1995, 1997-2000, Spring (S) 2000
Total Number of EPT taxa
0
5
10
15
20
25
30
35
40
45
50
1995
1997
1998
1999
2000S
2000F
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station
TRIBUTARY- Cabresto Creek
upstream fish hatchery
downstream fish hatchery, at USGS gage

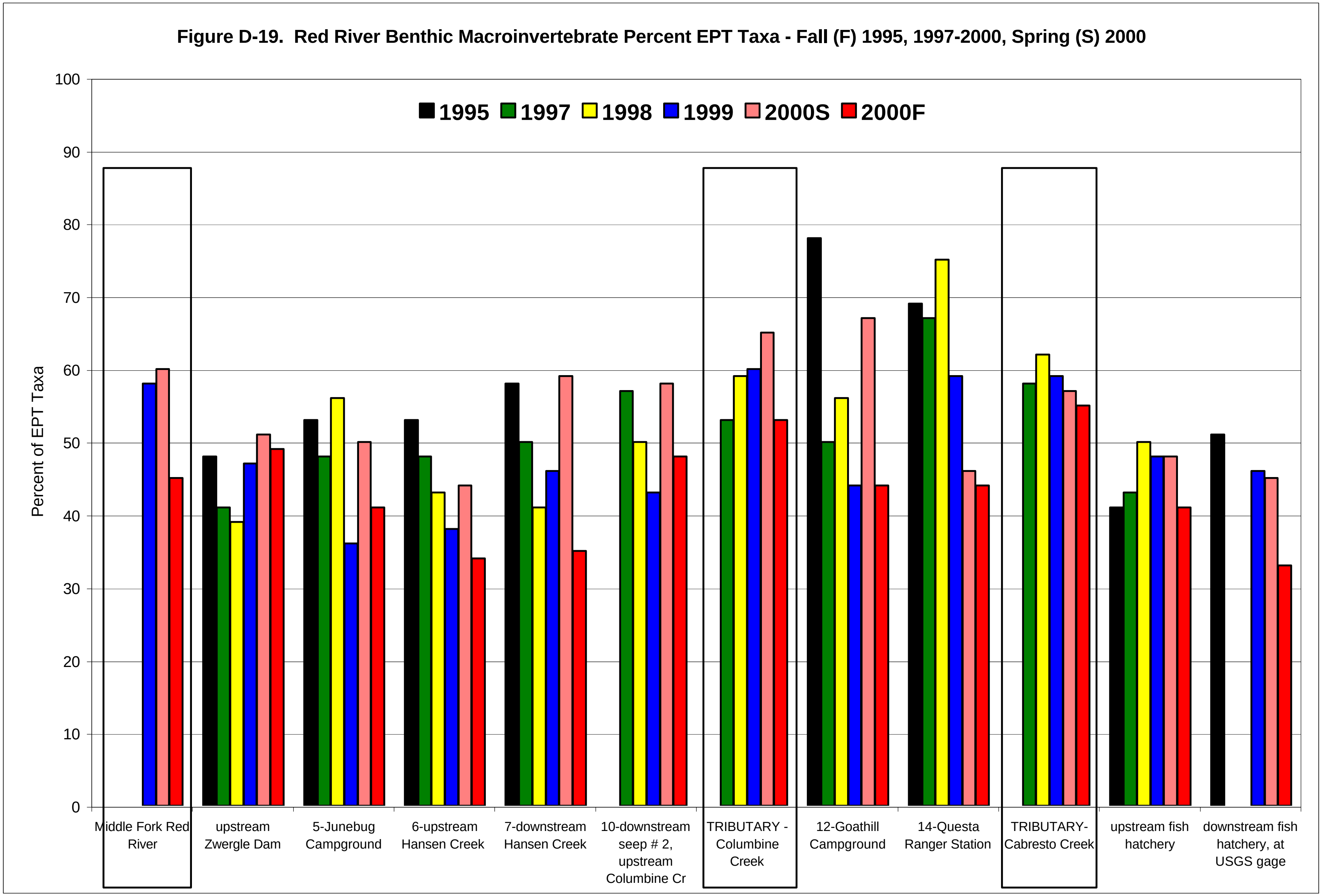


Figure D-19. Red River Benthic Macroinvertebrate Percent EPT Taxa - Fall (F) 1995, 1997-2000, Spring (S) 2000
1995
1997
1998
1999
2000S
2000F
Percent of EPT Taxa
0
10
20
30
40
50
60
70
80
90
100
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station
TRIBUTARY- Cabresto Creek
upstream fish hatchery
downstream fish hatchery, at USGS gage

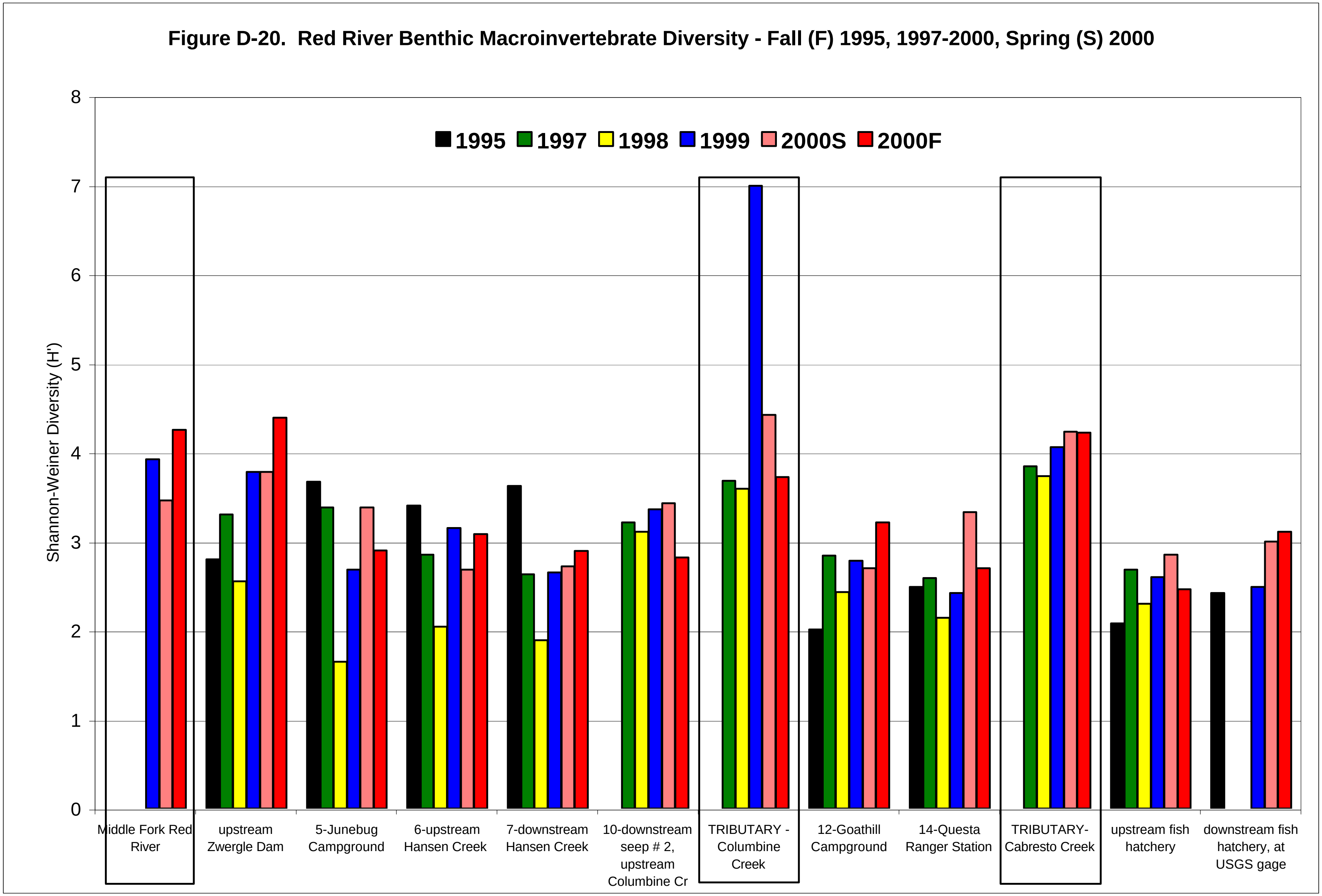


Figure D-20. Red River Benthic Macroinvertebrate Diversity - Fall (F) 1995, 1997-2000, Spring (S) 2000
1995 1997 1998 1999 2000S 2000F
Shannon-Weiner Diversity (H')
0
1
2
3
4
5
6
7
8
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station
TRIBUTARY- Cabresto Creek
upstream fish hatchery
downstream fish hatchery, at USGS gage

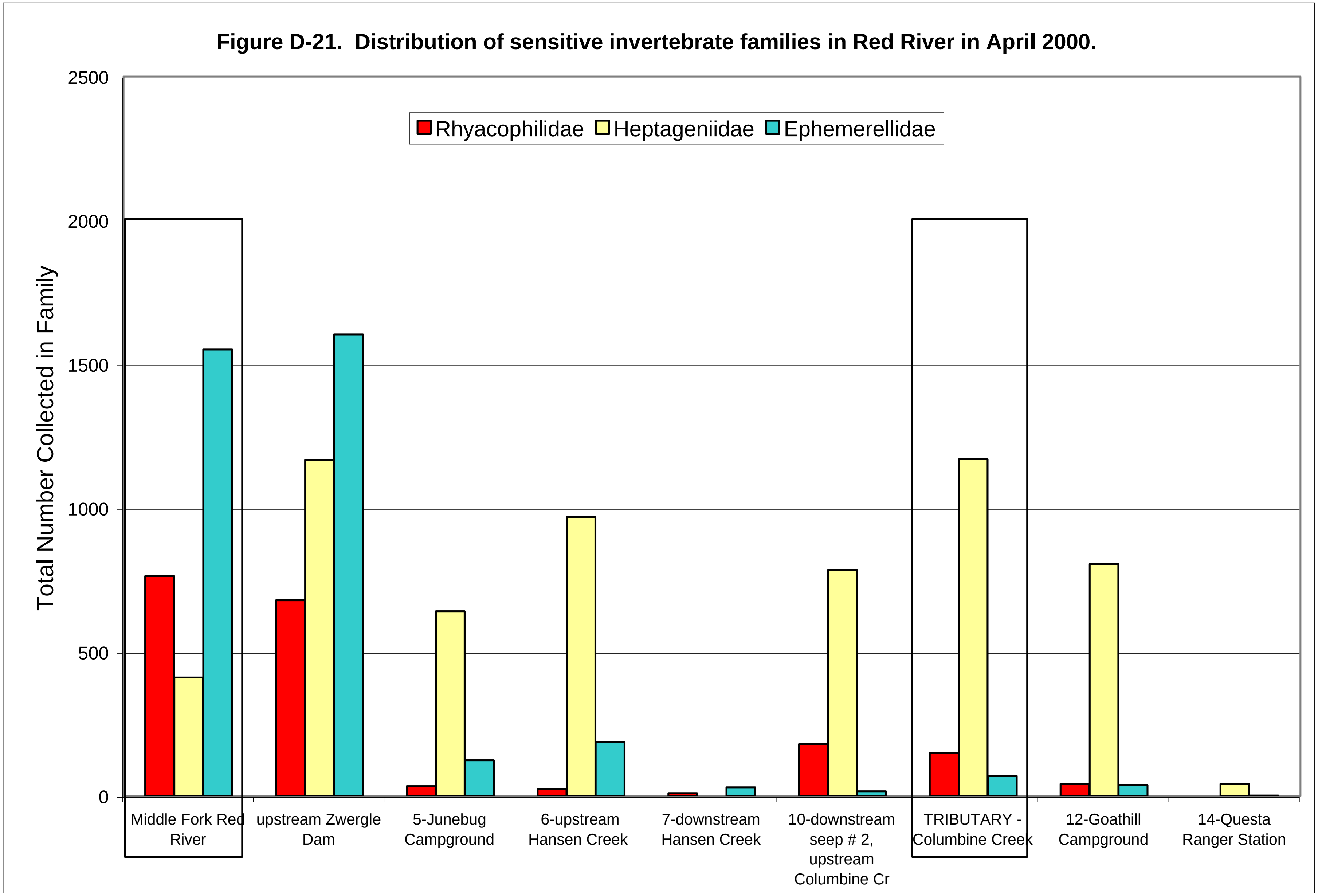


Figure D-21. Distribution of sensitive invertebrate families in Red River in April 2000.
Total Number Collected in Family
2500
2000
1500
1000
500
0
Rhyacophilidae
Heptageniidae
Ephemerellidae
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station

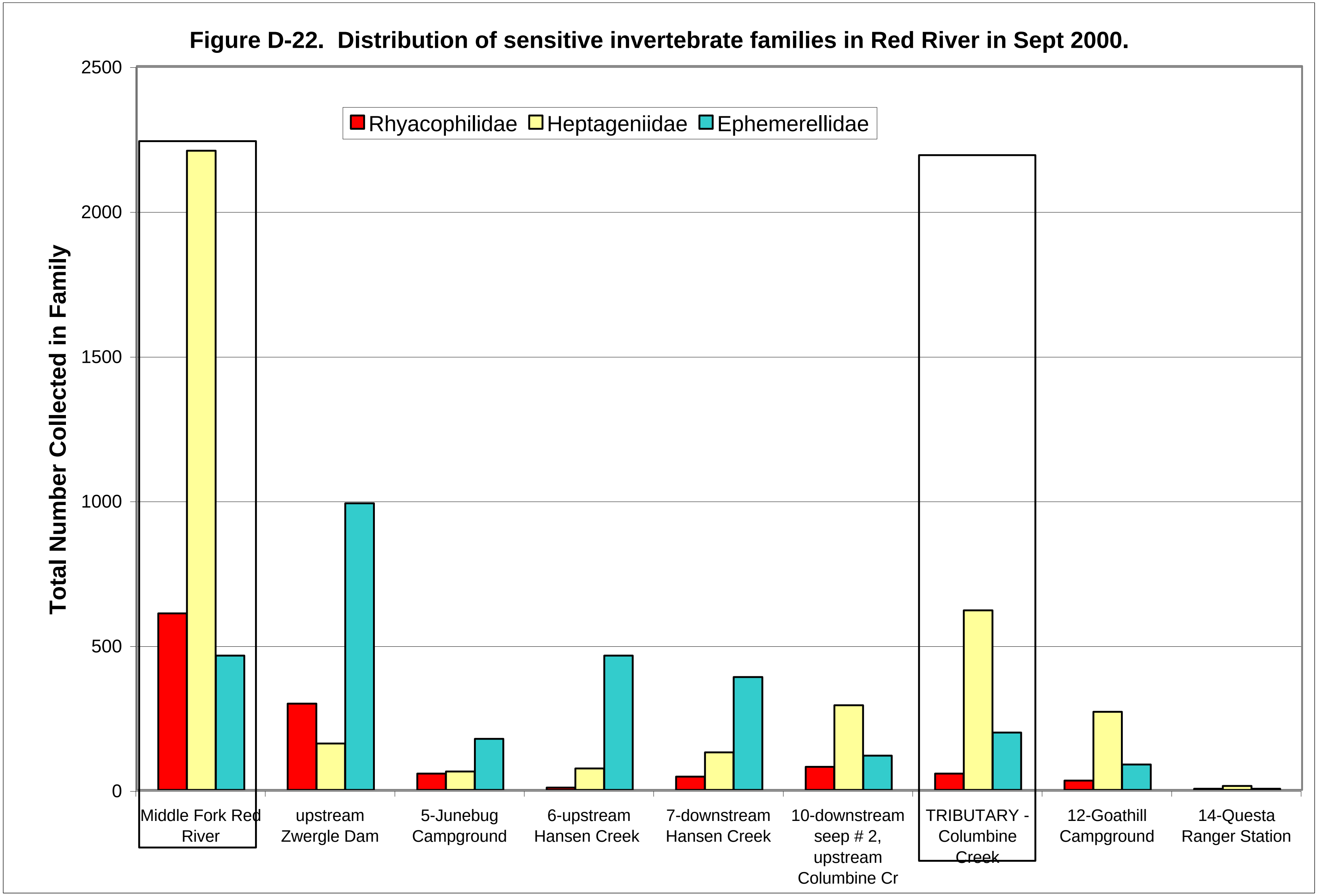


Figure D-22. Distribution of sensitive invertebrate families in Red River in Sept 2000.
Rhyacophilidae
Heptageniidae
Ephemerellidae
Total Number Collected in Family
2500
2000
1500
1000
500
0
Middle Fork Red River
upstream Zwergle Dam
5-Junebug Campground
6-upstream Hansen Creek
7-downstream Hansen Creek
10-downstream seep # 2, upstream Columbine Cr
TRIBUTARY - Columbine Creek
12-Goathill Campground
14-Questa Ranger Station

Appendix E: Conversion Factor Derivation

8.34 Conversion Factor Derivation

Million gallons/day **x** Milligrams/liter **x** 8.34 = pounds/day

10^6~~gallons~~/day **x** 3.7854 liters/~~1 gallon~~ **x** 10^{-3}gram/liter **x** 1 pound/454 ~~grams~~ = pounds/day

10^6 (10^{-3}) (3.7854)/454 = 3785.4/454

= 8.3379
= 8.34

Appendix F: Stream Bottom Deposit TMDL Data and Analysis

Clean stream bottom substrates are essential for optimum habitat for many fish and aquatic insect communities. The most obvious forms of degradation occur when critical habitat components such as spawning gravels (Chapman and McLeod, 1987) and cobble surfaces are physically covered by fines thereby decreasing intergravel oxygen and reducing or eliminating the quality and quantity of habitat for fish, macroinvertebrates, and algae (Lisle, 1989; Waters, 1995). Chapman and Mcleod (1987) found that size of bed material is inversely related to habitat suitability for fish and macroinvertebrates, and that excess sediment decreased both density and diversity of aquatic insects. Specific aspects of sediment-invertebrate relationships may be described as follows; 1) invertebrate abundance is correlated with substrate particle size; 2) fine sediment reduces the abundance of original populations by reducing interstitial habitat normally available in large-particle substrate (gravel, cobbles); and 3) species type, species richness, and diversity all change as particle size of substrate changes from large (gravel, cobbles) to small (sand, silt, clay) (Waters, 1995).

In order to assess the stream bottom for contaminants (mainly sediment) that may damage or impair aquatic life and significantly alter the physical properties of the bottom, physical measurements of the stream bottom substrate must be made alongside measurements being made of the biological component. Physical measurements (or indicators) of the stream bottom need to take into account those attributes or characteristics, which potentially promote the best physical habitat or environment for aquatic life independent of water quality. This concept can best be seen in Figure F1 (Plafkin et al., 1989) which shows the relationship between habitat and biological quality. More specifically, substrate that is plentiful, sufficiently large and varied, and is not surrounded or buried by fines appears to offer the best attributes for habitat suitability for many aquatic organisms adapted to such conditions.

In a study of 562 streams located in four northwestern states, Relyea et al., (2000) suggested **that changes to invertebrate communities as a result of fine sediment (2mm or less) occur between 20-35% fines.** Chapman and McLeod (1987) suggest that geometric particle size and percent of the bed surface covered by fines should both be used to define habitat quality. These two criteria can be ascertained by performing a **pebble count.** The pebble count procedure provides not only particle size distributions (d50, d84, etc.) and percent class sizes (% sand, % cobble, etc.), but offers a relatively fast and statistically reliable methodology for obtaining this information. In addition, relatively rapid temporal and spatial comparisons can be made at a number of sites within a watershed.

Although sufficient and varied sizes of stream bottom substrate are necessary for biological colonization, protection and reproduction, its full potential may not be realized if the substrate surfaces are surrounded by fine sediment. In streams with a large amount of sediment, the coarser particles become surrounded or partially buried by fine sediment. **Embeddedness** quantitatively measures the extent to which larger particles are surrounded or buried by fine sediment (Mc Donald et al., 1991). Studies by Bjorn et al., (1974, 1977) concluded **that approximately one-third embeddedness (33%) or less is**

probably the normal condition in streams. Above this condition, however, insect populations decline substantially as habitat spaces become smaller or entirely filled. By performing a **pebble count** and measuring **cobble embeddedness,** the stream bottom can be characterized as an aquatic habitat, compared to a reference site and then tentatively evaluated for impairment due to stream bottom deposits. **Confirmation** of impairment takes place when a stream site is **biologically assessed.**

The evaluation process for fines and embeddedness is shown in Table F1.

Table F1. Degree of aquatic life use support due to stream bottom deposits (sediment) as evaluated by increases in either fines or embeddedness, relative to Columbine Creek.[1]

Pebble Count Fines ≤ 2 mm (% increase over Columbine Creek)	**Embeddedness (% increase over Columbine Creek)**	**Degree of Aquatic Life Use Support (Presumptive+)**
0 – 10%	0 – 10%	Full Support, Comparable to Reference +, *
11 – 27%	11 - 27%	Supporting +
28 – 40%	28 – 40%	Partial Support +
> 40%	> 40%	Non-Support +

Adapted and modified from Figure F1, (i.e., 100 - 90% = 0 - 10%).
+ Biological assessment necessary for confirmation and statistical database.
* Raw percent values of 30% or less for fines and embeddedness at a study site should be evaluated as fully supporting regardless of the percent attained at the reference site.

Since the narrative standard for stream bottom deposits is centered around a biological component, any assessment or evaluation of a stream bottom using physical criteria, such as pebble count or embeddedness, needs to be confirmed using some type of bioassessment. A biological assessment using EPA's Rapid Bioassessment Protocol (Plafkin et al., 1989; Barbour et al., 1999) for macroinvertebrates was performed at both the reference and study sites to confirm the pebble count evaluation. This process is shown in Table F2.

Upon completion of physical and biological assessments for stream bottom deposits (sediments), a final assessment is determined from the following matrix table (Table F3). This is accomplished by taking the smaller of the increases between percent fines or embeddedness and matching it with the appropriate physical assessment use support category in the far left column.

Table F2. Biological Integrity Attainment Matrix

% Comparison to Columbine Creek	Biological Condition Category	Attributes +
>83%	Non-impaired	Comparable to best situation to be expected within ecoregion (watershed reference site). Balanced trophic structure. Optimum community structure (composition & dominance) for stream size and habitat quality.
79 – 54% *	Slightly Impaired	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
50– 21% *	Moderately Impaired	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
<17 *	Severely Impaired	Few species present. Densities of organisms dominated by one or two taxa.

\+ Biological attributes from EPA's Rapid Bioassessment Protocols for Use in Stream and Rivers (Plafkin et al., 1989). The Surface Water Quality Bureau has initiated a program of reassessing and refining the biomonitoring protocols and percentages used in this table to better reflect conditions in New Mexico waters.

* Recognizes the 4% gap between support designations. This allows for some best professional judgment (BPJ) by the data reviewer when the data are on the line between two different support designations.

Table F3. Final assessment matrix for determining aquatic life use support categories by combining physical (% fines & embeddedness) and biological assessments as sediment indicators.

Physical/Biological	Severely Impaired 0-17% +	Moderately Impaired 21-50% +	Slightly Impaired 54-79% +	Non-impaired 84-100%
Non-Support Fines and/or Embeddedness >40% increase *	Non-Support	Partial Support	Full Support, Impacts Observed	Full Support, Impacts Observed
Partial Support Fines and/or Embeddedness 28-40%increase *	Non-Support	Partial Support	Full Support, Impacts Observed	Full Support, Impacts Observed
Supporting Fines and/or Embeddedness 11-27% increase *	Non-Support **	Partial support**	Full Support, Impacts Observed	Full Support

Table F3. Final assessment matrix for determining aquatic life use support categories by combining physical (% fines & embeddedness) and biological assessments as sediment indicators.

Physical/Biological	Severely Impaired 0-17% +	Moderately Impaired 21-50% +	Slightly Impaired 54-79% +	Non-impaired 84-100%
Full Support Fines and/or Embeddedness <10% increase * or raw values of 30% or less at the study site.	Non-Support **	Partial Support**	Full Support, Impacts Observed **	Full Support

+ Recognizes the 4% gap between support designations. This allows for some best professional judgment (BPJ) by the data reviewer when the data are on the line between two different support designations.

* Reduction in the relative support level for the aquatic life use in this particular matrix cell is probably not due to sediment. It is most likely the result of some other impairment (temperature, D.O., pH, toxicity, etc.), alone or in combination with sediment.

** In cases where the percent increases of fines and embeddedness for a particular site are not in the same percent category or cell, use the category with the lower percentage between the two. An example, if fines are increased by 21 percent and embeddedness is increased by 9 percent relative to the reference site, use the <10% or full support category for use in the combination matrix.

Data collected for the listed tributary in the Red River watershed (Bitter Creek) and reference site (Columbine Creek) are shown in Table F4. The collected data for the listed tributaries was then compared to the reference site as summarized in Table F5.

Table F4. Physical and Biological Data Collected

Location	Biological Score	Pebble Count As % fines	Embeddedness As % fines
Columbine Creek Reference	*66*	*4%*	*34%*
Bitter Creek	30	81%	Data not collected

Table F5. Physical and Biological Assessment

Location	Biological Score (As % of Reference)	Pebble Count (As % of Reference)	Embeddedness (As % of Reference)	Final Assessment
Columbine Creek Reference	*100%*	*100%*	*100%*	*Full Support Reference*
Bitter Creek	45%(moderately impaired)	1,925%	Data not collected	Partial Support

References Cited

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, bnthic macroinvertebrates and fish*, 2nd edition. EPA 841-B-99-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

Bjornn, T.C., et al. 1974. *Sediment in streams and its effect on aquatic life*. University of Idaho, Water Resources Research Institute. Research Technical Completion Report Project B-025-IDA. Moscow, Idaho.

———. 1977. *Transport of granitic sediment in streams and its effects on insect and fish*. University of Idaho, College of Forestry, Wildlife and Range Science, Bulletin 17, Moscow, Idaho.

Chapman, D.W., and K.P. McLeod. 1987. *Development of criteria for fine sediment in Northern Rockies ecoregion*. United States Environment Protection Agency, Water Division, Seattle, Washington. Report 910/9-87-162.

Lisle, T. 1989. Sediment transport and resulting deposition in spawning gravels, North Coast California. *Wat. Resourc. Res*. 25 (6):1303-1319.

MacDonald, L.H. 1991. *Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska*. United States Environmental Protection Agency, Center for Streamside Studies, AR-10, College of Forestry and College of Ocean and Fishery Sciences, University of Washington. Seattle, Washington. EPA/910/9-91-001.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. *Rapid bioassessment protocols for use in streams and rivers.* U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, DC. EPA/444/4-89-001.

Relyea, C.D., C.W. Marshall and R.J. Danehy. 2000. *Stream Insects as Indicators of Fine Sediment*. Stream Ecology Center, Idaho State University, Pocatello, Idaho.

Waters T. 1995. *Sediment in streams sources, biological effects and control*. American Fisheries Society Monograph 7. Bethesda, Maryland.

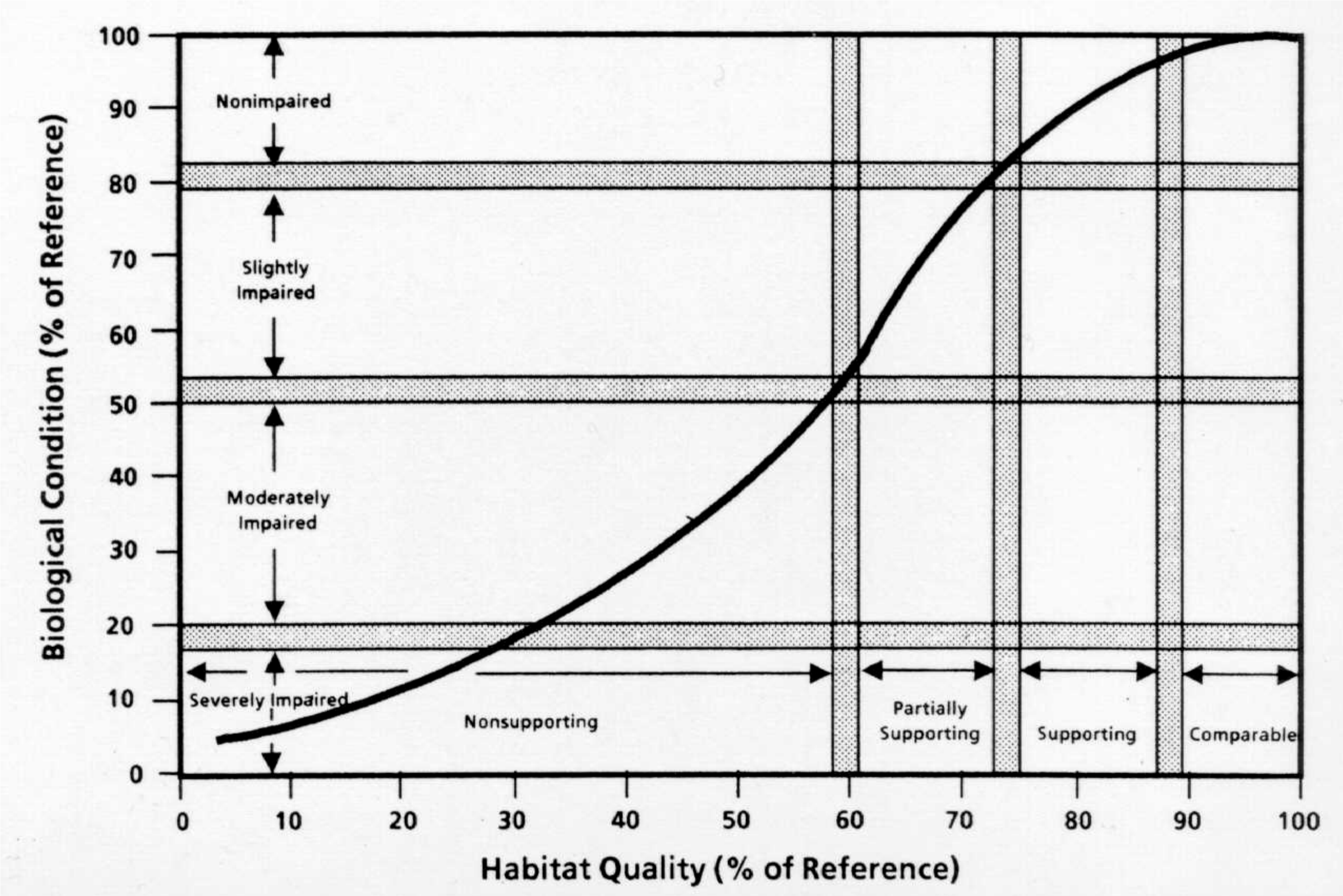
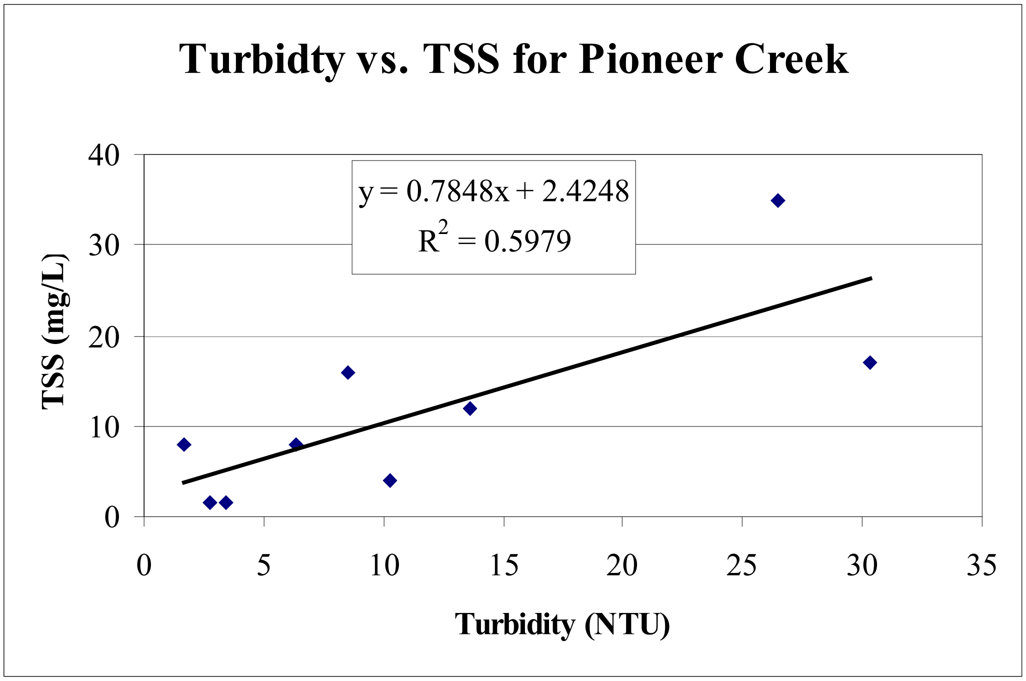


Figure F1. Relationship between habitat and biological condition (Plafkin *et al*, 1989)

Appendix G: Pioneer Creek Turbidity TMDL Data and Analysis

Relationship Between Total Suspended Sediment (TSS) and Turbidity for Pioneer Creek



Data used for TMDL Field Measurement Calculations in Table 12.

Sampling Site	Date	Turbidity (NTU)	TSS (mg/L)
Pioneer Creek	10-May-99	30.3	17
Pioneer Creek	11-May-99	26.5	35
Pioneer Creek	12-May-99	13.6	12
Pioneer Creek	13-May-99	10.3	4
Pioneer Creek	17-Aug-99	8.52	16
Pioneer Creek	18-Aug-99	3.4	1.5*
Pioneer Creek	25-Oct-99	2.76	1.5*
Pioneer Creek	26-Oct-99	6.36	8
Pioneer Creek	27-Oct-99	1.69	8

* This value was reported as less than 3 mg/L from the laboratory, so a value of 1.5 mg/L is used for calculations and analyses.

Appendix H: Pollutant Source(s) Documentation Protocol

POLLUTANT SOURCE(S) DOCUMENTATION PROTOCOL

New Mexico Environment Department
Surface Water Quality Bureau

July 1999

This protocol was designed to support federal regulations and guidance requiring states to document and include probable source(s) of pollutant(s) in their §303(d) Lists as well as the States §305(b) Report to Congress.

The following procedure should be used when sampling crews are in the field conducting water quality surveys or at any other time field staff are collecting data.

Pollutant Source Documentation Steps:

1). Obtain a copy of the most current §303(d) List.

2). Obtain copies of the Field Sheet for Assessing Designated Uses and Nonpoint Sources of Pollution.

3). Obtain digital camera that has time/date photo stamp on it from the Watershed Protection Section.

4). Obtain GPS unit and instructions from Neal Schaeffer.

5). Identify the reach(s) and probable source(s) of pollutant in the §303(d) List associated with the project that you will be working on.

6). Verify if current source(s) listed in the §303(d) List are accurate.

7). Check the appropriate box(s) on the field sheet for source(s) of nonsupport and estimate percent contribution of each source.

8). Photodocument probable source(s) of pollutant.

9). GPS the probable source site.

10). Give digital camera to Gary King for him to download and create a working photo file of the sites that were documented.

11). Give GPS unit to Neal Schaeffer for downloading and correction factors.

12). Enter the data off of the Field Sheet for Assessing Designated Uses and Nonpoint Sources of Pollution into the database.

13). Create a folder for the administrative files, insert field sheet and photodocumentation into the file.

This information will be used to update §303(d) Lists and the States §305(b) Report to Congress.

FIELD SHEET FOR ASSESSING DESIGNATED USES AND NONPOINT SOURCES OF POLLUTION

:ODES FOR USES NOT FULLY SUPPORTED

☐	HQCWF	=	HIGH QUALITY COLDWATER FISHERY	☐	DWS	=	DOMESTIC WATER SUPPLY
☐	CWF	=	COLDWATER FISHERY	☐	PC	=	PRIMARY CONTACT
☐	MCWF	=	MARGINAL COLDWATER FISHERY	☐	IRR	=	IRRIGATION
☐	WWF	=	WARMWATER FISHERY	☐	LW	=	LIVESTOCK WATERING
☐	LWWF	=	LIMITED WARMWATER FISHERY	☐	WH	=	WILDLIFE HABITAT

'ish culture, secondary contact and municipal and industrial water supply and storage are also designated in particular stream reaches where these ıses are actually being realized. However, no numeric standards apply uniquely to these uses.

REACH NAME:

SEGMENT NUMBER:
BASIN:
PARAMETER:

STAFF MAKING ASSESSMENT:
DATE:

:ODES FOR SOURCES OF NONSUPPORT (CHECK ALL THAT APPLY)

☐ <u>0100</u> INDUSTRIAL POINT SOURCES

☐ <u>0200</u> MUNICIPAL POINT SOURCES
☐ 0201 DOMESTIC POINT SOURCES

☐ <u>0400</u> COMBINED SEWER OVERFLOWS

☐ <u>1000</u> AGRICULTURE
☐ 1100 NONIRRIGATED CROP PRODUCTION
☐ 1200 IRRIGATED CROP PRODUCTION
☐ 1201 IRRIGATED RETURN FLOWS
☐ 1300 SPECIALTY CROP PRODUCTION (e.g., truck farming and orchards)
☐ 1400 PASTURELAND
☐ 1500 RANGELAND
☐ 1600 FEEDLOTS - ALL TYPES
☐ 1700 AQUACULTURE
☐ 1800 ANIMAL HOLDING/MANAGEMENT AREAS
☐ 1900 MANURE LAGOONS

☐ <u>2000</u> SILVICULTURE
☐ 2100 HARVESTING, RESTORATION, RESIDUE MANAGEMENT
☐ 2200 FOREST MANAGEMENT
☐ 2300 ROAD CONSTRUCTION or MAINTENANCE

☐ <u>3000</u> CONSTRUCTION
☐ 3100 HIGHWAY/ROAD/BRIDGE
☐ 3200 LAND DEVELOPMENT
☐ 3201 RESORT DEVELOPMENT
☐ 3300 HYDROELECTRIC

☐ <u>4000</u> URBAN RUNOFF/STORM SEWERS

☐ 5000 RESOURCES EXTRACTION
☐ 5100 SURFACE MINING
☐ 5200 SUBSURFACE MINING
☐ 5300 PLACER MINING
☐ 5400 DREDGE MINING
☐ 5500 PETROLEUM ACTIVITIES
☐ 5501 PIPELINES
☐ 5600 MILL TAILINGS
☐ 5700 MINE TAILINGS
☐ 5800 ROAD CONSTRUCTION/MAINTENANCE
☐ 5900 SPILLS

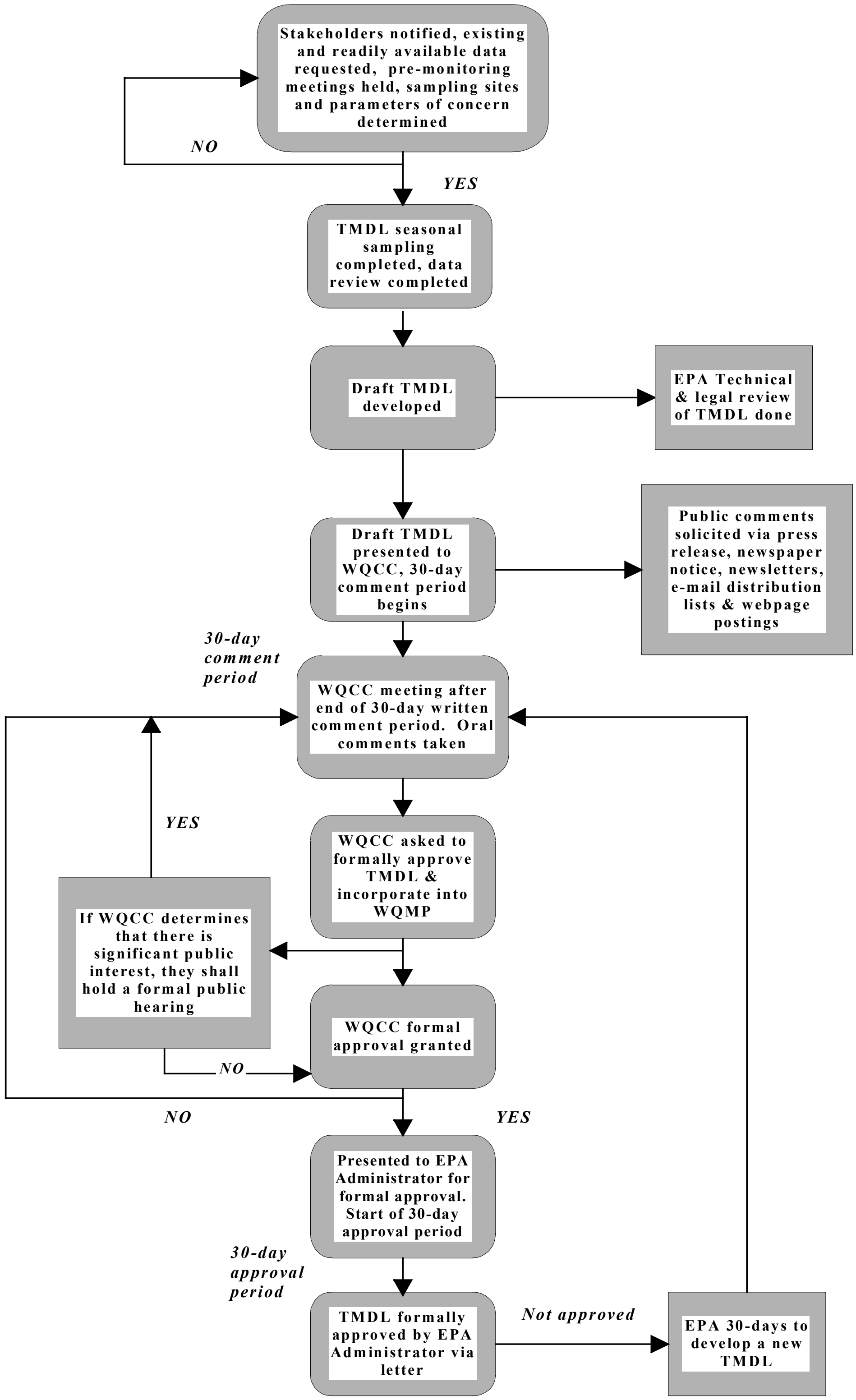
☐ <u>6000</u> LAND DISPOSAL
☐ 6100 SLUDGE
☐ 6200 WASTEWATER
☐ 6300 LANDFILLS
☐ 6400 INDUSTRIAL LAND TREATMENT
☐ 6500 ONSITE WASTEWATER SYSTEMS (septic tanks, etc.)
☐ 6600 HAZARDOUS WASTE
☐ 6700 SEPTAGE DISPOSAL
☐ 6800 UST LEAKS

☐ <u>7000</u> HYDROMODIFICATION
☐ 7100 CHANNELIZATION
☐ 7200 DREDGING
☐ 7300 DAM CONSTRUCTION/REPAIR
☐ 7400 FLOW REGULATION/MODIFICATION
☐ 7500 BRIDGE CONSTRUCTION
☐ 7600 REMOVAL OF RIPARIAN VEGETATION
☐ 7700 STREAMBANK MODIFICATION OI DESTABILIZATION
☐ 7800 DRAINING/FILLING OF WETLANDS

☐ <u>8000</u> OTHER
☐ 8010 VECTOR CONTROL ACTIVITIES
☐ 8100 ATMOSPHERIC DEPOSITION
☐ 8200 WASTE STORAGE/STORAGE TANK LEAKS
☐ 8300 ROAD MAINTENANCE or RUNOFF
☐ 8400 SPILLS
☐ 8500 IN-PLACE CONTAMINANTS
☐ 8600 NATURAL
☐ 8700 RECREATIONAL ACTIVITIES
☐ 8701 ROAD/PARKING LOT RUNOFF
☐ 8702 OFF-ROAD VEHICLES
☐ 8703 REFUSE DISPOSAL
☐ 8704 WILDLIFE IMPACTS
☐ 8705 SKI SLOPE RUNOFF
☐ 8800 UPSTREAM IMPOUNDMENT
☐ 8900 SALT STORAGE SITES

☐ <u>9000</u> SOURCE UNKNOWN

Appendix I: Public Participation Flowchart



Appendix J: Response to Comments

To be completed later.